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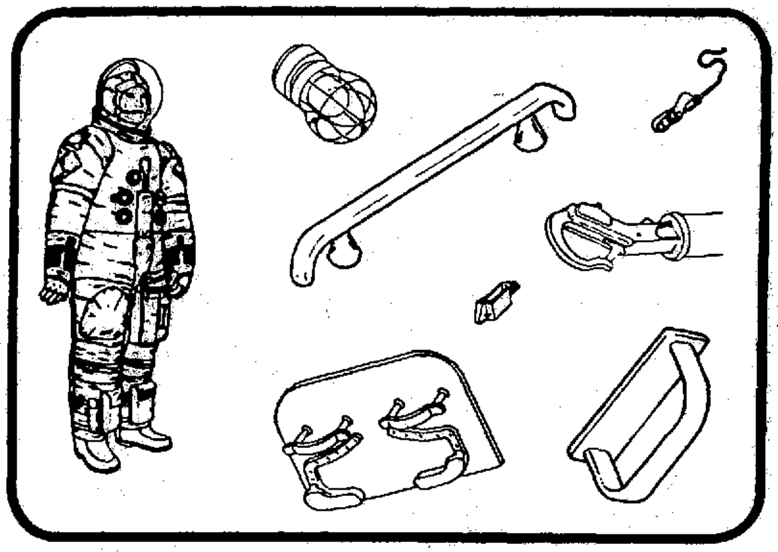

DEVELOPMENT OF AN EVA SYSTEMS COST MODEL

(NASA-CR-141636) DEVELOPMENT OF AN EVA SYSTEMS COST MODEL. VOLUME 3: EVA SYSTEMS COST MODEL Final Report (URS/Matrix Co., Houston, Tex.) 86 p HC $4.75 CSCL 06K

N75-17105

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VOLUME III: EVA SYSTEMS COST MODEL

FINAL REPORT

JANUARY 1975

URS MATRIX

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DEVELOPMENT OF AN EVA SYSTEMS COST MODEL

FINAL REPORT
CONTRACT NAS 9-13790

JANUARY 1975

VOLUME III
EVA SYSTEMS COST MODEL

PREPARED FOR:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS 77058

URS CORPORATION
URS/MATRIX COMPANY
LIFE AND ENVIRONMENTAL SCIENCES DIVISION
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URS MATRIX

FOREWORD

The EVA Systems Cost Model was developed as part of NASA Study Contract No. NAS 9-13790 entitled, "Development of an EVA Systems Cost Model." The basic objective of the total study (four major tasks) was to provide extravehicular data to assist mission, experiment and payload planners and designers in quantifying the cost of EVA to future vehicles and payloads. The report herein contains cost data in terms of the weight, volume, expendables, etc. associated with EVA support equipment and crewman consumables. The model does not attempt to relate the costs to a dollar value. The information and data are derived entirely from EVA systems and equipment developed and qualified on previous space programs and Space Shuttle information available to the contractor during report preparation.

The work was administered under the technical direction of Mr. David C. Schultz of the EVA and Experiments Branch, Crew Procedures Division, Flight Operations Directorate of the Lyndon B. Johnson Space Center, Houston, Texas.

The total contract report consists of the following three volumes:

Volume I: Design Guides Synopsis--EVA Equipment

Volume II: Shuttle Orbiter Crew and Equipment Translation Concepts
and
EVA Workstation Concept Development and Integration

Volume III: EVA Systems "Cost" Model

This report (Volume III) presents an EVA Systems Cost Model based on proposed EVA equipment for the Space Shuttle Program. General information on EVA crewman requirements in a weightless environment and an EVA capabilities overview are provided.

However, because of the fluid status of Shuttle-provided accommodations for payloads, a definite cost distribution between the Shuttle Orbiter and payloads was not available at final report preparation. The Model user must, therefore, consult the latest revision of the NASA-JSC Space Shuttle Systems Payload Accommodations Document, JSC 07700, for current payload charges.

The terms "mission planners" and "experiment/payload designers" are used frequently throughout the report. The contractor's use of these terms have no implications toward identifying or indicating the NASA center, organization, or personnel that may be responsible for vehicle, experiment, or payload design/selection. The terms only refer to the assemblage of government, industrial, institutional, or foreign organizations involved in developing a payload/vehicle to be included in the Space Shuttle Program with no indication toward specifying a governing organization. Since the NASA-JSC is responsible for developing the complement of EVA supporting systems for the Space Shuttle, the experiment and payload planners and designers will basically be designing their hardware around those EVA systems. The payload planning and designing teams will be involved in specifying the quantity of each EVA support component based on the specific requirements of their experiments.

PREFACE

The United States' manned spaceflight programs through Skylab have qualified EVA as an operational technique for performing orbital and deep space mission functions. The Space Shuttle Orbiter, scheduled to begin test flights in the late 1970's, will afford the opportunity to perform a variety of tasks outside the spacecraft--perhaps to ensure crew safety or from economic considerations. Current plans call for an EVA capability to be provided on both the Shuttle orbital flight tests and throughout the operational Shuttle era. Based on the previous Skylab missions, it is anticipated that each future space program will provide for many planned EVA functions and, almost certainly, contingency provisions to enhance safety and mission success. Contingency provisions will include mandatory support systems and equipment in the spacecraft inventory for crewman safety and rescue.

Since the EVA capability currently appears to be a requirement for many future manned spaceflights, it is desirable to provide the mission planner and the experiment and payload designers information and data for utilizing man in extravehicular (EV) operations. This study provides an overview of the factors that must be acknowledged when considering man in an EV capacity, provides conceptual EV workstations and translation aid designs, and defines the impact that EVA may have on the payloads through the development of an EVA Systems Cost Model.

This report (Volume III) provides a set of worksheets which allow the payload designers to estimate the cost of employing EVA from the Shuttle Orbiter. The worksheets are formatted for use by the designer when the candidate tasks are identified and the EVA requirements estimated. The Model is arranged as a series of charts and tables providing costs in terms of weight, volume, expendables, etc. associated with an extravehicular capability.

The Model is designed primarily to assist payload planners and designers by including EVA hardware and consumables that may be charged to the payload.

Current EVA Cost Model information will be maintained by the Procedures Branch (CG2), Crew Training and Procedures Division, Flight Operations Directorate, Johnson Space Center, Houston, Texas. EVA Cost Model inquiries should be addressed to Mr. David C. Schultz (713-483-3094) or Mr. John H. Covington (713-483-4794. The Model will be updated as Shuttle EVA programs progress and Cost Model revisions issued as conditions warrant.

ACKNOWLEDGMENTS

The NASA Technical Monitor for this study was Mr. David C. Schultz, Chief, Procedures Branch (CG2), Crew Training and Procedures Division, Flight Operations Directorate, Johnson Space Center, Houston, Texas. Contract monitoring assistance was provided by Mr. John H. Covington and Mr. Raymond G. Zedekar in the Integrated Procedures Section of the Crew Training and Procedures Division. Appreciation is expressed to Dr. Stanley Deutsch, Director, Bioengineering Division, Office of Life Sciences, NASA Headquarters, for his efforts in arranging for the conduct of the study.

Valuable assistance in obtaining information and photographic material was supplied by personnel within the NASA Johnson Space Center. Special appreciation is due Mr. Lawrence O. Corcoran/EW631, Mr. John H. Covington/CG251, Mr. Robert R. Kain/CG251, Mr. Joseph J. Kosmo/EC921, Mr. Curtis J. LeBlanc/ED121, Mr. James W. McBarron/EC911, Mr. Charles W. Wheelwright/EW531, Mr. Stewart L. Davis/LO, Mr. Maurice A. Carson/EC6 and Mr. Robert L. Spann/EC9.

The contractor Principal Investigator for the study was Mr. Nelson E. Brown, Division Director, Life and Environmental Sciences Division, URS/Matrix Company, URS Corporation. Principal contributors within the URS/Matrix Company were Mr. Billy K. Richard and Mrs. Betty K. Bielat.

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ACRONYMS AND ABBREVIATIONS

AES	Advanced Extravehicular Suit
ALSA	Astronaut Life Support Assembly
AMU	Astronaut Maneuvering Unit
ATM	Apollo Telescope Mount
CBRM	Circuit Breaker Relay Module
CCA	Communications Carrier Assembly
CSM	Command Service Module
CWG	Constant Wear Garment
DAC	Data Acquisition Camera
EMU	Extravehicular Mobility Unit
EV	Extravehicular
EVA	Extravehicular Activities
FTB	Film Transfer Boom
ft	Foot
HHMU	Hand-Held Maneuvering Unit
JSC	Johnson Space Center
kg	kilogram
lb	Pound
LCG	Liquid Cooling Garment
LSS	Life Support System
m	Meter
MEED	Microbial Environment Exposure Device
MMU	Manned Maneuvering Unit

NASA	National Aeronautics and Space Administration
NBS	Neutral Buoyancy Simulation
OWS	Orbital Workshop
PLSS	Portable Life Support System
PRS	Personnel Rescue System
SIM	Scientific Instrument Module
SLSS	Secondary Life Support System
SOP	Secondary Oxygen Pack
SSA	Space Suit Assembly
UCD	Urine Collection Device

DEFINITION OF TERMS

Many of the terms used in this report have various connotations within the NASA and aerospace community. Some are readily familiar only to personnel involved directly in the EVA field. Therefore, as an aid to the reader, several of the perhaps unfamiliar EVA terms are defined below.

PLANNED EVA — Those activities planned prior to launch to complete a Shuttle mission function.

UNSCHEDULED EVA — Those activities which are not planned prior to the mission but which may be required to achieve payload operation success or enhance overall mission success.

CONTINGENCY EVA — Those activities related to safety of the crew, e.g., remedial or rescue activities.

SPACE SUIT ASSEMBLY (SSA) — A SSA consists of the following major items which constitute the basic space suit:

- Integrated torso-limb suit
- Gloves
- Controls and displays
- In-suit electrical harness
- Bioinstrumentation system
- Helmet
- Boots

ASTRONAUT LIFE SUPPORT ASSEMBLY (ALSA) — The ALSA, designated as the Space Shuttle EVA Life Support System, consists of:

- Portable Life Support System (PLSS)
- Secondary Oxygen Pack (SOP)
- Battery
- LiOH Cartridge

EXTRAVEHICULAR MOBILITY UNIT (EMU) — An EMU consists of the following items which make up a complete extravehicular support system:

- Space Suit Assembly (SSA)
- Liquid Cooling Garment (LCG) or Constant Wear Garment (CWG)
- Life Support System (LSS)
- Secondary Life Support System (SLSS)
- Extravehicular Visor Assembly
- Urine Collection Device (UCD)
- Fecal Containment Subsystem (FCS)
- Communications Carrier Assembly (CCA)

ADVANCED EXTRAVEHICULAR SUIT (AES) — Any space suit in the development stage with "improvements" over existing suits.

LIQUID COOLING GARMENT (LCG)	A garment worn in direct contact with the skin which incorporates liquid coolant tubes to accomplish the primary body cooling requirements.
CONSTANT WEAR GARMENT (CWG)	A one-piece, short-sleeved garment covering the crewman's torso and feet, leaving the neck, head and lower arm exposed. May be worn EVA in place of LCG but depends on workload, time, etc.
LIFE SUPPORT SYSTEM (LSS)	A primary system, either portable or umbilical, which supplies the required breathing medium and pressure to provide a viable atmosphere for the suited EVA crewman.
SECONDARY LIFE SUPPORT SYSTEM (SLSS)	A backup system serving the same functions as the LSS. Usually a self-contained O_2 purge unit with less capacity than the primary LSS.
EXTRAVEHICULAR VISOR ASSEMBLY	A visor attached to the helmet to provide visual, thermal, impact, and micrometeoroid protection during EVA.
URINE COLLECTION DEVICE (UCD)	A flexible bag type device worn inside the space suit used to temporarily store urine while wearing the SSA.
FECAL CONTAINMENT SUBSYSTEM (FCS)	The FCS consists of a "diaper" type garment which acts as a comfort pad while wearing the PGA.
COMMUNICATIONS CARRIER ASSEMBLY (CCA)	The CCA consists of a head fitted assembly incorporating redundant microphones and earphones which provide the EMU system communications link to the crewman.
BIOINSTRUMENTATION SYSTEM	The bioinstrumentation system is a rectangular section of woven Teflon cloth containing pockets and restraining features which house signal conditioners, dc-dc converters, and crewman identification modules used in the EVA transmission of critical body functions.
PORTABLE LIFE SUPPORT SYSTEM (PLSS)	A completely self-contained life support system usually carried on the back of the EVA crewman. The units normally contain communications, telemetry, and secondary life support capabilities.
OXYGEN PURGE SYSTEM	A unit functioning in the same capacity as a Secondary Life Support System. Usually associated with a PLSS.
WATER IMMERSION SIMULATION (WIS)	Refers to EVA simulations/hardware evaluations when the suited crewman is totally submerged and made neutrally buoyant.

FILM TRANSFER BOOM (FTB) — Electrically and manually actuated extendible boom used to transfer film modules a distance of approximately 9.1 m. (30 ft.) on Skylab. Also used in various aerospace antenna and experiment applications.

A MODEL FOR ESTIMATING EVA COST

PURPOSE OF THE MODEL

Extravehicular activity (EVA) has been proposed as a method of accomplishing numerous tasks on the Space Shuttle and future spacecraft. Experimenters, mission planners, and spacecraft designers are interested in the most economical means of servicing their experiments and payloads, deploying/retrieving satellites, and collecting experiment data. The spacecraft designers and mission planners are concerned with spacecraft external inspections, performing minor maintenance activities and emergency safety/rescue operations. The Model contained in this report will provide a means of estimating the cost to the payload of placing a crewman (crewmen) outside the vehicle to perform a desired task. The Shuttle Orbiter will provide the equipment and expendables to support limited EVAs for planned or contingency EVA operations (ref. 1). The payloads will furnish the cost of EVA provisions which exceed the Orbiter baseline EVA accommodations.

The EVA Systems Cost Model is designed for the experimenter or mission planner who is not thoroughly knowledgeable in the EVA field. The experiment or payload equipment need not be designed before the Model is employed. In fact, it is preferred that the Model be exercised in the early payload planning and design stages since the costs and provisions for EVA or alternative techniques are likely to affect designs. The Model will not define all costs or quantify exact costs of providing EVA but is intended as a planning device to aid in the comparison of EVA with other techniques.

In order for potential Shuttle users to effectively propose the use of EVA, they should be familiar with the EVA support equipment utilized on previous space programs and equipment being considered for the Space Shuttle. The reader is referred to Volumes I and II of this final report for both quantitative and qualitative information on EVA equipment and interface requirements. A summary of man's proven performance capabilities in the space environment is contained in later sections of this report.

MODEL LIMITATIONS

The EVA Systems Cost Model has evolved from a NASA desire to provide timely assistance to Space Shuttle users in identifying an economical means of supporting future payloads on-orbit. However, in the late 1974 Space Shuttle system payload accommodation studies were still being conducted. The issue of distributing EVA-associated costs to either the Orbiter or payloads remains fluid. The EVA "cost" entries contained in this Model may not be charged to the payload unless the number of required EVA support items exceed those already in the Shuttle Orbiter inventory.

In late 1974 the Orbiter was scheduled to provide hardware for a two-man EVA capability including expendables for three EVAs. Two of these EVAs could be used by the payloads for planned or contingency operations while one EVA would always be reserved for rescue. The Orbiter would also provide personnel rescue systems (PRS) for two additional crewmen since the prime rescue mode is currently via EVA to a rescue Orbiter. The payloads will provide a PRS for crewmen in excess of four. Supporting hardware concepts, such as transfer tunnels to payloads, EVA egress modules associated with manned sortie laboratory and external airlocks (proposed in mid-1974) have not been allocated relative to Orbiter or payload charges.

To identify what EVA equipment is charged to the payload, the most current revision to the NASA-JSC "Space Shuttle Systems Payload Accommodations" document, JSC 07700, Volume XIV, must be used in conjunction with the Model. The Model will provide costs in terms of the weight, volume, expendables, etc. directly associated with EVA systems and support hardware utilized on the Shuttle. The Model does not provide costs incurred by NASA for EVA hardware design, development and qualification since these costs will not be apportioned to the Shuttle users. A dollar cost is not provided--available data relative to cost per Shuttle flight may be obtained from reference 2.

Estimates of EVA costs may be affected by further developments in the EVA hardware field. For example, improved designs of the suit joints and access

provisions may reduce donning and doffing times from the pre- and post-EVA periods, respectively. The increased mobility of the proposed Shuttle suits could also decrease EVA mission time, particularly for translation and work-site ingress/egress. Improvements in portable life support systems may change the configuration of these systems. The improvements may affect the weight, volume, and time required for systems checkout, donning, doffing, servicing, etc.

At present, a basic argument used to justify EVA as an operational technique is that the capability already exists on the Shuttle; why not use it. The Space Shuttle will afford EVA capability for the crewmen according to current study directives. However, the fact that an EVA capability exists does not imply that EVA is the most cost effective method to perform on-orbit tasks; trade studies must be made.

The following statement was taken from the Space Shuttle Systems Payload Accommodations, Level II Program Definition and Requirements, JSC 07700, Volume XIV, Revision C, July 3, 1974:

> "The Shuttle Orbiter provides the equipment and expendables to support Extravehicular Activities (EVA) for planned or contingency EVA operations."

Since the Orbiter must provide the EVA capability in the event rescue is necessary, the EVA equipment carried aboard each flight may be used by the payload community. Therefore, the major costs to the payloads are weight, volume, and crew/equipment expendables required in excess of Orbiter-provided EVA hardware. Crew time for end-to-end EVA missions must also be considered. Such "charges" are not unique to EVA but will be assessed to the payload independent of the system/technique used in servicing the payload. Weight and volume penalties, of course, reduce the weight and volume of the payload scientific equipment that can be carried on an individual flight should that flight be weight critical. Similarly, EVA crew time reduces the amount of on-orbit time available to conduct experiments and reduce data, as would the crew time used in the preparation, checkout, and operation of systems such as teleoperators and remote manipulators.

The Cost Model is arranged as a series of charts and tables presenting each dependent variable (e.g., suit weight, life support system volume, LiOH canister weight) as a function of the independent variables (e.g., number of crewmen EVA, EVA duration). Task description is included as an input to the Cost Model in the flow diagram shown in Figure 1.1 to allow package sizes, masses, translation distances, etc. to be included in the Model.

The basic procedure to be followed by the user in exercising the EVA Systems Cost Model involves three preliminary steps:

1. Prepare a description of the mission to be performed via EVA

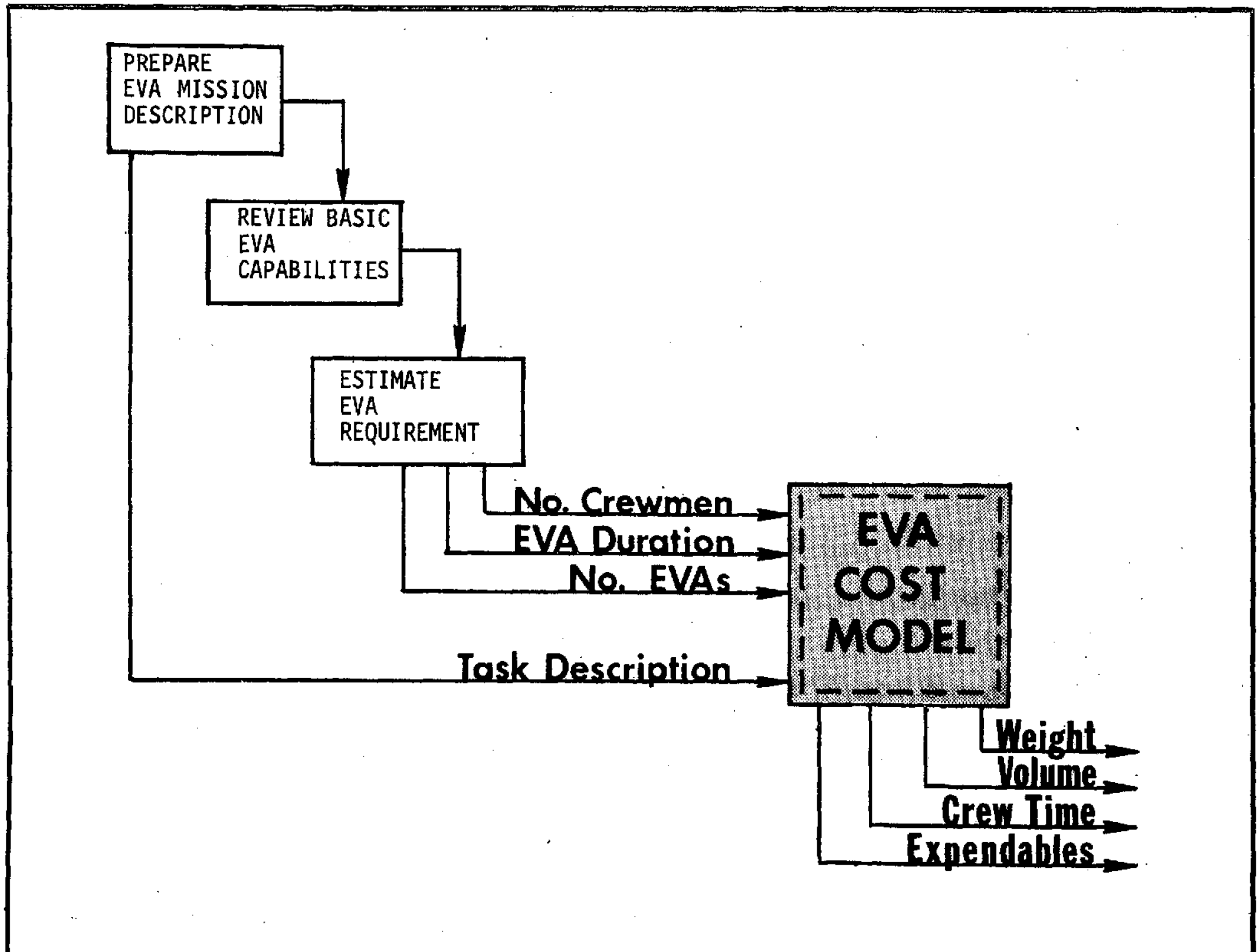

FIGURE 1.1: Cost Model Flow Sequence

2. Review EVA capabilities data, if necessary

3. Estimate EVA requirements

MISSION DESCRIPTION (EXAMPLE)

The model user is required to describe the EVA mission in terms of the major tasks to be performed, number of task repetitions, travel distance, work-site access functions required and other principal operations. As an example, the description may be stated as:

> Replace 12 equipment modules and 8 portable data collection systems accessible from the exterior of the Large High Energy Observatory D while the payload is berthed in the Orbiter payload bay. The worksite is located approximately 12.2 m. (40 ft.) from the Orbiter airlock and requires 6.1 m. (20 ft.) of the payload bay crewman translation system and 6.1 m. (20 ft.) of payload dual handrail to reach the worksite. A crewman restraint capability will be required for stabilization at two worksites while actuating four overcenter door release mechanisms and replacing modules at each worksite. Operation of the door release mechanisms will require a simple torque bar. The modules to be transported range in size from 45.7 x 25.4 x 20.3 cm. (18 x 10 x 8 in.) to 101.6 x 45.7 x 45.7 cm. (40 x 18 x 18 in.) and mass from 18.1 kg. (40 lbs.) to 68.0 kg. (150 lbs.). Module replacement operations will require common mechanic type tools. Replacement modules are stowed in the aft payload bay approximately 14.6 m. (48 ft.) from the airlock. Checkout operations will be required following module replacement and prior to cabin ingress.

REVIEW EVA CAPABILITIES

Demonstrated on-orbit, transearth, and simulated EVA capabilities are described in Section 2.0 of this report to enable the user to identify EVA requirements based on proven EVA capabilities. If not familiar with previous space EVA operations, the model user should review the representative capabilities overview provided in Section 2.0 prior to estimating the EVA requirements.

ESTIMATING EVA REQUIREMENTS (EXAMPLE)

After completing the above steps, the user will prepare an estimate of the number of EVA crewmen required, the number of EVAs required, the duration of each EVA and the ancillary support equipment. Requirements for the EVA mission described above may be estimated as:

> Three EVAs requiring two crewmen for 4.5 hours each. Crewman No. 1 will perform the replacement activities at the worksites (with assistance from crewman No. 2 as required). Crewman No. 2 will perform operations associated with a cargo transfer system located at the payload bay stowage area. Two portable crewman restraint systems will be required, a cargo transfer system, tool kit, auxiliary lighting and a still camera mount.

The payload in the above example must also provide expendables for one two-man EVA and handrails for worksite access from the payload bay.

With the three basic preparatory steps completed, the user enters the cost charts of the Model.

The following EVA capabilities overview is provided to aid the model user in estimating the EVA requirements for a particular task. The data are presented as: (1) flight results, and (2) ground based simulation activities. Although flight results are more desirable as a measure of crew performance capability, the requirement or opportunity to verify the simulation activities on-orbit may not have been presented. Representative orbital and transearth EVA activities from the Gemini, Apollo and Skylab Programs are provided to depict proven EVA capabilities to date. Ground based simulations in several cases have attempted to establish the upper limits of crewman capabilities in weightlessness.

Many of the early in-flight EVA tasks were performed in conjunction with the evaluation of EVA crewman and equipment restraints and stabilization hardware. Many of the early restraint systems and EVA techniques have been vastly improved, and the data may not be totally representative of current capabilities. However, the EVA information is provided to show capabilities using various restraint systems. Flight and simulated capabilities are arranged by EVA task in chronological order beginning with the Gemini Program.

EVA FLIGHT EXPERIENCE

Gemini EVA Functions--One-Man Tasks

Task	Restraint System
S013 experiment camera mounting	Tethers
Photograph M410 color plate retrieval	Tethers
Fluid quick-disconnect hookup	Foot Restraints
Spacecraft (GATV) tether attachment	Vehicle/handholds
Change film (EVA camera)	Tethers
Telescoping handrail deployment	Tethers
Tether hookup (restraint evaluation)	Vehicle/handholds
Install camera	Tethers

Task	Restraint System
Disconnect & connect electrical connectors	Foot restraints
Cutting cables & fluid hose	Foot restraints
Saturn bolt tightening (using tools)	Foot restraints
Cleansing command pilot's window	Vehicle/handrail
Torquing bolthead with torque wrench	Tethers/foot restraints
Camera mounting (16 mm)	Tethers
Connect tether hooks	Foot restraints
Unstow Astronaut Maneuvering Unit (AMU) control arm	Foot restraints
Unstow oxygen hose	Foot restraints
Apply 11.3 kg. (25 lb.) force to work surface	Foot restraints
Apply torque of 2.3 kgm. (200 in-lb) with 22.9 cm. (9 in.) wrench	Foot restraints
Apply 1.2 kgm. (100 in-lb) torque with 12.7 cm. (5 in.) wrench	Foot restraints

The foot restraints (essentially a rigid overshoe fixed at the worksite in which the crewman inserted the EVA spacesuit boots) were used during Apollo EVAs. The restraints were also referred to as "dutch shoes" or "golden slippers.

Apollo EVA Functions

The major EVA functions performed on the Apollo Program (excluding lunar surface exploration) are listed below (ref. 5):

- Hand-Held Maneuvering Unit (HHMU) evaluation
- Umbilical evaluation (tether dynamics)
- Velcro pad evaluation (removal, holding ability, shear, tension)
- Package retrieval (micrometeorite)
- Astronaut Maneuvering Unit (AMU) preparation (unstow controller arms, umbilicals, etc.)
- Package retrieval from remote vehicle

- Handhold evaluation (cylindrical, oval, various cross-sections)
- Operate electrical and fluid connectors
- Evaluate life support systems
- Deploy, conduct, and retrieve MEED experiments
- Retrieve 38.6 kg. (85 lb.) panoramic camera - 49 m. dia. x .16 m. (19.3 in. dia. x 6.2 in.)
  - Translate to Scientific Instrument Module (SIM) bay - 3.05 m. (10 ft.) using single handrails and handholds
  - Retrieve camera
  - Transport camera from SIM bay to Command Service Module (CSM) hatch - approximately 3.05 m. (10 ft.)
- Retrieve 12.2 kg. (27 lb.) mapping camera cassette - 26.7 cm. dia. x 21.6 cm. (10.5 in. dia. x 8.5 in.)
  - Translate to SIM bay - approximately 3.05 m. (10 ft.) using handrails and handholds
  - Retrieve cassette
  - Transport cassette from SIM bay to CSM hatch - approximately 3.05 m. (10 ft.)
  - Three round trips were made to the SIM bay on Apollo 15 during a 38-minute EVA period (retrieval tasks could have been accomplished in less time, if desired)

The Apollo EVA functions were accomplished during both Orbital and trans-earth missions. EVA life support systems were evaluated for the lunar surface missions, photographic data retrieved during planned EVAs and stabilization hardware qualified for the later Apollo and Skylab missions.

Skylab EVA Functions

The Skylab Program initially planned to conduct six EVAs distributed over three missions with a total of 29 man-hours outside the vehicle. The purposes

of the Skylab planned EVAs were to retrieve solar astronomy data through on-orbit exchange of Apollo Telescope Mount (ATM) experiment film and to retrieve thermal control coating samples (experiment D024). However, during Skylab launch, a portion of the meteoroid shield on the Orbital Workshop (OWS) became detached and was torn from the vehicle. One of the OWS solar array panels was also torn away and the other array blocked by debris and only partially deployed. The Skylab power generation capability was reduced to one half, and loss of the meteoroid shield caused interior overheating.

In order to restore and maintain Skylab operational status, ten EVAs were conducted for a total of 82.5 man-hours outside the Skylab vehicle. In addition to deploying the remaining OWS solar array and erecting a solar shield (to replace the missing meteoroid shield), 18 unplanned mission objectives and 13 in-flight repair tasks were accomplished. The elapsed time for the longest Skylab EVA mission was 6 hours, 53 minutes. The major EVA functions accomplished on the Skylab Program are listed below in two categories--planned EVA tasks and contingency EVA operations.

Planned EVA Tasks:

- Module/cargo handling and transporting (solar astronomy film data, experiment containers, tools, etc.)
- Cargo transfer system manual deployment and operation (clothesline system)
- Powered cargo transfer system operation (extendible booms)
- Equipment module exchange (film magazine containers)
- Retrieve various space environment exposure samples (experiment D024)
- Retrieve and install magnetospheric particle composition collectors (experiment S230)
- Data acquisition camera (DAC) operation (16 mm camera)

Contingency EVA Operations:

- Severed restraining strap and deployed an OWS solar array panel
- Deployed a twin-pole sun shade over missing meteoroid shield
- Restrained solar astronomy aperture door in open position
- Repaired a circuit breaker relay module (CBRM)
- Cleaned solar astronomy equipment occulting disk
- Positioned material samples on exterior Skylab ATM truss work
- Mounted equipment and conducted experiments (Micrometeoroid Particle Collection--S149; Coronograph Contamination Measurements--T025; X-Ray/UV Solar Photograph--S020; Far UV Camera (S201))
- Installed electrical cables to gyroscope package
- Removed solar astronomy experiment aperture door ramp using common tools
- Secured the pitch axis of a microwave radiometer/scatterometer/altimeter (S193 antenna)
- Repaired a solar astronomy experiment film magazine filter wheel (experiment S054)
- Took temperature readings of experiment equipment exterior
- Operated hand-held cameras

Many of the Skylab contingency EVA tasks were performed using common hand tools, tools slightly modified for EVA and "makeshift" items produced aboard the spacecraft. Numerous tasks were performed without prior training from less-than-desirable restraint and stabilization provisions which proved man's versatility and capability to perform operational tasks outside the vehicle.

Simulation Results

Numerous ground based simulations have been conducted in neutral buoyancy facilities and "zero-g" aircraft to evaluate EVA hardware and crewman capabilities.

Several of the more significant simulation results, applicable to the Space Shuttle, are listed below (ref. 6 and 7).

- Neutral Buoyancy Simulation (NBS) used to verify transfer of a 744.1 kg. (1650 lbs.), 4.02 m^3 (142 ft^3) package at average velocity of approximately .09 m/sec (0.3 ft/sec) using dual handrails (ref. 6 and 7)
- NBS used to verify transfer of a 744.1 kg. (1650 lbs.), 4.02 m^3 (142 ft^3) package at average velocity of approximately .06 m/sec (0.2 ft/sec) using single handrail (ref. 6 and 7)
- NBS has indicated that average translation rates of .229 m/sec (0.75 ft/sec) are realistic while transporting a 145.9 kg. (320 lbs.) mass (ref. 6 and 7)
- NBS used to verify two-man deployment of simulated payload weighing 3855.6 kg. (8,500 lbs.). Dimensions were approximately 5.8 m. (19 ft.) by 1.07 m. dia. (3.5 ft. dia). No limit has been set on the size and mass of the largest payloads to be handled. Up to 29,484 kg. (65,000 lbs.) is being considered (ref. 8)
- Assuming use of single handrail (ref. 9):
  - NBS used to establish .3 to .6 m/sec (1.0 to 2.0 ft/sec) IVA translation velocities
  - Average translation velocity .3 m/sec (1.0 ft/sec) while EVA
- NBS has indicated that crewmen can apply approximately 27.2 kg. (60 lb.) force in a forward direction on an object .7 to 1.3 m. (28 to 52 in.) above the floor where foot restraints (Skylab) are provided (ref. 10)
- NBS has indicated that crewmen can apply in excess of 27.2 kg. (60 lb.) force in an isometric (force reacting) horizontal pulling fashion to a lever approximately .3 m. (1 ft.) above the floor where foot restraints (Skylab IVA) are provided (ref. 10)
- NBS has indicated that horizontal pulling forces are greater than horizontal pushing forces using foot restraints

- Aircraft simulations of package handling and transfer along single and dual handrails up to 10.2 x .8 x .6 m. (40 x 30 x 24 in.) package size
- Various aircraft simulations of workstation ingress/egress, crewman translation, cargo handling, worksite tasks, etc.

The EVA capabilities cited above do not constitute the total spectrum of activities that have been successfully performed on previous space programs or simulation activities. The total EVAs and simulations conducted by NASA and industry are far too numerous to include in a single document. The EVA operations/tasks overview provided above is intended to aid the mission planner and designer in perceiving EVA applications for the Shuttle payloads and assist in estimating EVA requirements to accomplish the candidate mission.

The time required to prepare for and terminate operations performed outside the spacecraft may be a factor of on-orbit time available to conduct experiments, perform servicing operations, refurbish payloads, etc. Crew time must be considered in the mission design for prep- and post-activities independent of the technique used (e.g., remote manipulator system, manned EVA, teleoperator) to perform the tasks.

The total time required for EVA preparation and post-EVA functions is provided in Table 3-1 (ref. 11) to permit the Model user to estimate the total on-orbit time required for an EVA mission. Space is provided for the planner to incorporate the estimated time to perform the EVA tasks from airlock hatch open to hatch closed. Total EVA time can be recorded in the table by the Model user for planning purposes.

Pre-EVA Crew Time

The time required for the crewmen to prepare the spacecraft systems and the EVA support hardware for external activities is directly related to the efficient design of the man/system interface, the number of manual operations required, the location of the items used in the preparation functions, etc. The preparation time required for EVA on previous missions has acted somewhat as a deterrent in selecting EVA for future missions. On the previous space programs, donning of the EVA gear was only a moderate fraction of the time required as compared to vehicle and EVA systems checkout and preparation. However, the development of advanced EVA support systems (e.g., life support system, pressure suits) and collocation of EVA associated items with the manual functions on future missions are designed to reduce the preparation and termination time. If prebreathing is required, other mission operations can be performed during the prebreathing period. The number of crewmen required to participate in EVA, the number assisting in EVA preparation, and the duration of each EVA will affect the total preparation time.

TABLE 3-1: EVA Preparation and Post-EVA Time Requirements

PRE-EVA FUNCTION	CREW TIME (min.)	REMARKS/EXPLANATION
START PREBREATHE	5	Prebreathing equipment (rebreather, O_2 umbilical, and mask) is unstowed, connected and operationally checked. Crewman starts prebreathing and continues for up to 2 hours until the scheduled start of EVA preparation activities. During this 2-hour period, the crewman may perform required non-EVA related activities.
START EVA PREPARATION		
CABIN PREPARATION	10	Airlock and lower deck area are configured for life support equipment and suit donning. Donning aids, such as restraint devices and temporary stowage compartments, are unstowed and positioned, as required.
EQUIPMENT PREPARATION	15	Equipment required for EVA (i.e., suits, life support equipment, tethers, etc.) are unstowed and positioned for donning. Preliminary checkout of the equipment will be performed, as required.
SUIT DONNING	30	Inflight suits are doffed and stowed. EVA and ancillary equipment (i.e., crewman's waste management system and liquid cooling garment) are donned. Crewman connects to the airlock water cooling umbilicals.
ALSA DONNING	15	Life support equipment (backpack) donning would be completed if an integrated EMU is provided.
HELMET/GLOVE DONNING	15	After completion of prebreathe, crewman will doff the rebreather and don comm carrier, helmet and gloves. O_2 purge of EMU will then be performed.

TABLE 3-1: EVA Preparation and Post-EVA Time Requirements (continued)

PRE-EVA FUNCTION	CREW TIME (min.)	REMARKS/EXPLANATION
COMMUNICATION CHECK	10	Comm check between the ALSAs and the Orbiter comm system is made. ALSA telemetry is checked. Backup ALSA comm modes are also checked.
INTEGRITY CHECK	5	An integrity check of the EMUs is performed prior to completion of airlock depress. This is a gross check of the EMU to verify that all connections are made and that leakage is acceptable.
AIRLOCK DEPRESS	6	Airlock depress will be performed by the EVA crewman. Depress will be interrupted at least once to verify EMU and airlock integrity.
HATCH OPENING	4	After opening and securing outer airlock hatch, the crew will initiate start-up of ALSA cooling. After cooling has been established, crew will begin the EVA.
SUBTOTAL	110	EVA preparation only
FOR USE BY PLANNER		
EVA MISSION OPERATIONS TIME ESTIMATE		
POST-EVA FUNCTIONS	CREW TIME (min.)	REMARKS/EXPLANATION
HATCH CLOSING	5	After completion of EVA, crewman ingresses the airlock; ALSA cooling is shut down and outer airlock hatch closed.
AIRLOCK REPRESS	5	Crewman represses airlock and verifies airlock integrity.

TABLE 3-1: EVA Preparation and Post-EVA Time Requirements (continued)

POST-EVA FUNCTIONS	CREW TIME (min.)	REMARKS/EXPLANATION
HELMET/GLOVE DOFFING	10	After suit pressure is equalized with ambient, crewman doffs and stows helmet and gloves and connects to the Orbiter water cooling system. The ALSA is deactivated.
ALSA DOFFING	15	ALSA is doffed and secured in the airlock. If integrated EMU is used, ALSA is doffed with the suit.
SUIT DOFFING	30	ALSA and suit are doffed and secured if an integrated EMU is used. Otherwise, suit is doffed during this period. Crewman also doffs ancillary suit equipment and dons flight suit. Suits and ancillary equipment are stowed unless suit drying is required.
ALSA RECHARGE	20	ALSA consumables are replaced during this period. ALSA is prepared and secured for next EVA. Loose equipment, such as tethers and cameras, is stowed.
SUIT DRYING	20	Suit drying is initiated, if required. If not required, suits and ancillary equipment are stowed, and the lower deck area/airlock are returned to pre-EVA configuration.
FOR USE BY PLANNER		
TOTAL		

NOTE: Timeline and sequences outlined are typical of those required for Shuttle EVA preparation and post-EVA activities. They are subject to change as equipment required to support EVA is better defined and procedures are optimized.

Table 3-1 presents an estimate of crew time required for EVA preparation. Values are given for facility preparation, suit donning, life support system donning, airlock depressurization, etc.

Post-EVA Crew Time

The factors which determine EVA termination time (i.e., post-EVA time) include EVA equipment doffing, EVA support systems recharging/drying, equipment stowage, and vehicle systems post-EVA operations. The equipment and systems are serviced as quickly as practical following EVA in order to have operational hardware available for contingency circumstances and future scheduled EVAs. As in the preparation for EVA, the number of crewmen required in EVA functions, the number assisting in EVA termination, and the duration of each EVA will affect the total termination time.

Estimated crew times that are required after completion of the EVA tasks are also presented in Table 3-1. Values are given for airlock pressurization, suit doffing, equipment servicing, etc. It should be noted that many options are available for efficiently performing other tasks (i.e., crewmen not participating in EVA operations) during post-EVA functions and should be considered relative to the total space mission.

SECTION 4.0 CREWMAN AND CARGO TRANSFER SYSTEM SELECTION GUIDELINES

Numerous crewman translation and cargo transportation devices and systems were proposed during previous spaceflight programs for assisting the crewman during transfer tasks. Of the many transfer/transport systems conceived/ developed, only a limited number remain as candidates for future space missions. Single and dual handrails of a specified cross section, compatible to the space-suit gloves, have been efficiently used on previous EVA missions. Cargo transfer booms (i.e., electrically powered extendible booms with manual backup) were used during the Skylab EVA mission to retrieve scientific data. An Astronaut Maneuvering Unit (AMU) evaluated on Skylab offers potential free-flying systems for transferring man and cargo on the Space Shuttle and future programs. It is anticipated that the crewman translation and package transportation aids will not vary considerably from those currently available. Only the weight of the EVA transfer/transportation systems required in excess of the baselined EVA crewman translation provisions inside the payload bay will be charged to the payload utilizing EVA. The Shuttle Orbiter will provide mobility aids for EVA translation through the payload bay to the aft bulkhead, and one remote manipulator system--RMS (i.e., currently baselined--late 1974).

Table 4-1 provides weight and volume values for several space qualified crewman translation and cargo transportation aids/devices. The table is provided primarily as an aid to the mission and payload planner in defining qualified systems available for Space Shuttle use. A cargo mass and volume range is suggested for use with each of the cargo transportation systems/methods. Three major cargo size levels in terms of mass and a corresponding volume are established by the columns in the table. The <160 lbs and <10 ft^3; 160-1600 lbs and 10-140 ft^3; and >1600 lbs and >140 ft^3 package mass and volume (in kilogram and meter^3; lbs and ft^3) levels have been demonstrated to be meaningful dividing points. The translation/transportation aids which are considered appropriate for each package mass and volume range are designated with a "yes." The aids considered inadequate for the range are designated with a "no." The assignments of translation/transportation aids to each range were made on the basis of demonstrated in-flight and simulation results.

To use the table:

1. Establish the mass and volume of the module/cargo that must be transferred from payload requirements.

2. Identify the column heading within which the cargo falls.

3. Obtain the least complex and least expensive translation/transportation aid by identifying the first "yes" as the selected column is descended.

4. Obtain weight and volume estimates of the hardware required from the weight and volume columns of the appropriate charts in Section 5.0 of this report.

Since the translation/transportation guidelines table is only a planning tool, extreme cases are not accommodated. Consequently, extremely cumbersome objects and objects with small mass and/or small volume having awkward shapes may not be as easily transported by the same system as more standardized packages. In such cases, discretion must be used in specifying a cargo transportation method/system.

TABLE 4-1: Crewman and Cargo Transfer System Selection Guidelines

CARGO TRANSFER AIDS	CREWMAN ONLY NO CARGO	CARGO MASS AND VOLUME						REMARKS/APPLICATIONS
		CLASS I		CLASS II		CLASS III		
		SI	CONV.	SI	CONV.	SI	CONV.	
		<73 kg. and <.3 m³	<160 lbs. and <10 ft³	73-730 kg. and .3-3.9 m³	160-1600 lbs. and 10-40 ft³	>730 kg. and >3.9 m³	>1600 lbs. and >40 ft³	
NO AIDS	yes	no		no		no		IVA ONLY--SHORT DISTANCES FREE FLOATING
VEHICLE EQUIPMENT	yes	yes		no		no		EXISTING VEHICLE EQUIPMENT ALONG TRANSLATION ROUTE OTHER THAN TRANSLATION AIDS
HANDHOLDS	yes	yes		no		no		PACKAGE TETHERED TO CREWMAN DURING TRANSFER
SINGLE TRANSLATION RAIL	yes	yes		no		no		USED ON SKYLAB--PACKAGE HANDHELD AND TETHERED TO CREWMAN
DUAL TRANSLATION RAIL	yes	yes		yes		no		USED ON SKYLAB--RATED HIGHLY BY CREWMEN
CLOTHESLINE SYSTEM	yes	yes		yes		no		MANUALLY ACTUATED ON SKYLAB
EXTENDIBLE BOOM	no	yes		yes		no		ELECTRICALLY ACTUATED CARGO BOOM
SHUTTLE MANIPULATOR ARMS	no	yes		yes		yes		REMOTELY ACTUATED FROM SHUTTLE CABIN
MANNED MANEUVERING UNIT	yes	yes		yes		requires study		PACKAGE ATTACHED TO MMU FOR FREE SPACE TRANSFER

The tables and charts which follow will allow an estimate to be made of the costs of an existing EVA capability to perform payload tasks on the Space Shuttle. By combining the task requirements for the selected task(s) with the EVA capabilities information provided in the previous sections, an estimate can be derived of the weight, volume, expendables, and crew time required for an EVA capability to support the task.

No costs are provided for automated or teleoperator systems. It is likely that such systems could be competitive with EVA for many tasks. The remotely operated Shuttle remote manipulator system, for example, may be useful in handling large payloads. Free-flying or restrained teleoperators may find application in the servicing of certain automated payloads. These systems will most likely require similar (or perhaps more) crew time, weight, and volume as the EVA operations when all impacts are identified and supporting data are available.

The tables contained in this section are based primarily on Skylab EVA systems and EVA systems being developed for the Space Shuttle Orbiter. Provisions for additional entries into each cost chart are included to reflect advanced EVA systems resulting from NASA EVA/IVA support systems study and development contracts, and in-house NASA programs.

Cost tables and charts are included for the major EVA areas and are listed below:

- Shuttle Space Suit Assembly and Support Equipment
- Astronaut Life Support Assembly
- EVA Supporting Equipment
- Crewman Translation and Cargo Transfer Aids
- Consumables and Expendables (Crewman and Equipment)
- Tools

- Orbiter Configuration Options
  - EVA Egress Module
  - EVA Airlock
- Manned Maneuvering Unit (MMU)
- Portable EVA Workstations and Retraints
- Crewman and Cargo Transfer Systems Selection Guidelines
- EVA Preparation and Post-EVA Activities

<u>Including</u>

- EVA Costs Summary/Working Charts
- Forms for Updating and Maintaining the Model

Descriptions of the procedures for using each Cost Model chart are included in a narrative discussion of the EVA equipment requirements. Appendix A contains an EVA mission cost scenario as an additional aid in explaining the use of the Model. Appendix B contains Cost Model worksheets, and Appendix C provides Cost Model updating forms.

5.1 SHUTTLE SPACESUIT ASSEMBLY AND SUPPORT EQUIPMENT

It is anticipated that the spacesuit being considered for the Space Shuttle Program will be a combination of the best features of the current suits. The suit may provide improved mobility, don/doff characteristics, lower energy expenditure, etc. over current models. This will essentially preclude an option to the payload planner or designer in selecting a spacesuit assembly for use during EVA payload servicing.

Since each payload servicing operation will vary with respect to task requirements, performance time, workload, crewmen required, etc., the payload user will be involved in selecting the quantities of certain pressure suit support equipment. Each payload EVA servicing mission is considered from an end-to-end basis in selecting the quantity of gear necessary. Spare pressure suits and supporting hardware items are based on the number of EVA crewmen, total pressurized time, and severity of use per mission. As a minimum, the following suit components are required by each EVA crewman based on one EVA mission:

- One Integrated Torso Limb Suit Assembly
- One Liquid Cooling Garment (LCG)
- One Helmet
- One Extravehicular Visor Assembly (EVVA)
- One Pair EV Gloves
- One Communication Carrier Assembly (CCA)
- One In-Suit Drinking Device
- One Urine Collection Device
- Water for LCG
- One Personal Radiation Dosimeter
- One Passive Radiation Dosimeter
- One Wrist Tether

- One In-Suit Electrical Harness
- One Bioinstrumentation System

The payload/experiment planner will only be responsible for determining the number of each EVA item needed and the weight and volume of the items required in excess of the EVA accommodations provided by the Orbiter. The Orbiter will provide to the payload two complete spacesuit assemblies (components listed above) and crew expendables for two EVA missions.

Table 5-1 provides data to permit the planner to estimate the weight and volume of spacesuits and supporting equipment for Shuttle based EVAs. The total spacesuit assembly configured for EVA is provided on the first line in the body of the table. The remaining entries are components which make up the total spacesuit assembly. The supporting equipment is identically formatted: the major horizontal line contains the total package parameters while the entries beneath the major horizontal lines are components which constitute the package. All spacesuit components listed are those currently (late 1974) being considered for the Shuttle Program. The weights and volumes are estimates based on information available to the contractor.

To use the table, the planner is required to:

1. Establish the number of EVA crewmen that will be required to perform tasks.
2. Establish the number of EVAs required to perform the tasks.

If item 1 or 2 above does not exceed a value of 2, the payload would not be charged for spacesuits or support equipment. If item 1 or 2 exceeds a value of 2, proceed below.

3. Obtain additional component weights and volumes by descending the appropriate column to the row containing the component required. The weight and volume of the item are given in the cell at the intersection of the row and column.

4. Establish the number of in-flight additional components (i.e., spare "items") required, based on 1 and 2 above.

5. Adjust component weights and volumes by multiplying the values given by the number of EVAs required in excess of 2 according to the "Number of Items Required" columns. <u>If the Remarks column contains an entry of "1 per crewman per EVA," these components must be replaced after each EVA. The weights and volumes of these components must be multiplied by the number of additional "items" established in 4 above.</u> Record in "FOR USE BY PLANNER" column.

6. Total weight and volume of additional spacesuits and support equipment may be obtained by adding down the "FOR USE BY PLANNER--TOTALS" column after adjustments for the number of EVAs, number of EVA crewmen, and spare "items" are made.

NOTE: If the number of crewmen required to perform EVA tasks does not exceed 2, and the total number of EVAs does not exceed 2, none of the costs in Table 5-1 will be charged to the payload.

TABLE 5-1: Shuttle Spacesuit Assembly and Support Equipment

SPACE SUIT ITEMS \ PARAMETER	WEIGHT		VOLUME		FOR USE BY PLANNER		REMARKS	FOR USE BY PLANNER			
					NUMBER OF EVA CREWMEN REQUIRED	NUMBER OF ITEMS REQUIRED		TOTAL ITEM WEIGHT		TOTAL ITEM VOLUME	
	kg	lbs	cm^3	ft^3				kg	lbs	cm^3	ft^3
TOTAL SPACE SUIT ASSEMBLY	31.2	68.8	TBD	TBD			1 REQUIRED PER CREWMAN--INCLUDES ALL ITEMS LISTED BELOW EXCEPT: (1) CREW PROVISIONS; AND (2) FLIGHT CREW EQUIPMENT				
• INTEGRATED TORSO LIMB SUIT ASSEMBLY	21.8	48.0	123,912	4.35			1 PER CREWMAN				
• LIQUID COOLING GARMENT (LCG)	1.6	3.6	7,080	.25			1 PER CREWMAN				
• HELMET	1.4	3.0	28,320	1.0			1 PER CREWMAN				
• EXTRAVEHICULAR VISOR ASSEMBLY (EVVA)	2.37	5.0	19,824	.70			1 PER CREWMAN				
• EV GLOVES	1.4	3.0	1,982	.07			1 PAIR PER CREWMAN				
• COMMUNICATION CARRIER ASSEMBLY (CCA)	.73	1.6	--	--			1 PER CREWMAN				
• IN-SUIT DRINKING DEVICE	.18	.4	2,832	.10			1 PER CREWMAN <u>PER EVA</u>				
• URINE COLLECTION DEVICE	.18	.4	5,664	.20			1 PER CREWMAN <u>PER EVA</u>				
• WATER FOR LCG	.45	1.0	--	--			INITIAL CHARGE ONLY				
• PERSONAL RADIATION DOSIMETER	.04	.1	85	.003			1 PER CREWMAN				
• PASSIVE RADIATION DOSIMETER	.04	.1	85	.003			1 PER CREWMAN				
• WRIST TETHER "D" RING	.14	.3	--	--			NONE REQUIRED--IS TASK DEPENDENT				
• IN-SUIT ELECTRICAL HARNESS	.18	.4	--	--			1 PER CREWMAN				
• BIOINSTRUMENTATION SYSTEM	.86	1.9	850	.03			1 PER CREWMAN				

TABLE 5-1: Shuttle Spacesuit Assembly and Support Equipment (continued)

SPACE SUIT HARDWARE / PARAMETER	WEIGHT kg	WEIGHT lbs	VOLUME cm^3	VOLUME ft^3	FOR USE BY PLANNER: NUMBER OF EVA CREWMEN REQUIRED	FOR USE BY PLANNER: NUMBER OF ITEMS REQUIRED	REMARKS	FOR USE BY PLANNER: TOTAL ITEM WEIGHT kg	TOTAL ITEM WEIGHT lbs	TOTAL ITEM VOLUME cm^3	TOTAL ITEM VOLUME ft^3
CREW PROVISIONS	.68	1.5	850	.03			OPERATION OPTION--NOT INCLUDED IN SPACESUIT ASSEMBLY				
• COMFORT GLOVES	.04	.1	283	.01			OPTIONAL				
• WATCHBAND	.01	.02	283	.01			OPTIONAL				
• CHRONOGRAPH	.06	.13	283	.01			TASK DEPENDENT				
FLIGHT CREW EQUIPMENT	.65	1.34	736	.026			OPERATION OPTION--NOT INCLUDED IN SPACESUIT ASSEMBLY				
• PEN LIGHT	.17	.38	57	.002			TASK DEPENDENT				
• PENCIL	.02	.05	28	.001			TASK DEPENDENT				
• MARKER PEN	.01	.03	28	.001			TASK DEPENDENT				
• POUCH, SWISS ARMY KNIFE	.02	.05	28	.001			OPTIONAL				
• POCKET ASSY., SCISSORS	.04	.08	28	.001			OPTIONAL				
• POCKET ASSY., CHECKLIST	.19	.42	280	.010			TASK DEPENDENT				
• DATA LIST	.15	.33	280	.010			TASK DEPENDENT				
							FOR USE BY PLANNER: TOTALS				

5.2 LIFE SUPPORT SYSTEMS

According to current guidelines, the EVA Life Support Systems (LSS) used on the Space Shuttle will consist of a self-contained, back-mounted portable LSS similar to the Apollo lunar surface units. The Apollo portable LSS will require modification to meet the requirements of zero gravity operation and satisfy extended Space Shuttle Orbiter and payload missions.

The development of new LSS or modification of existing designs will dictate the basic LSS units/equipment for use on all Shuttle EVA missions. Similar to pressure suit selection responsibilities, a choice of primary EVA life support systems will not be available to the payload planner. Designation of the quantity of life support systems, in-flight component spares, expendables, etc. required for an EVA mission will be the responsibility of the payload planning/designing teams of NASA and experimenters based on the specific payload requirements. The weight and volume impact of the LSS to the payload is of interest to the Shuttle user only if the Shuttle EVA accommodations are exceeded. As a minimum, the following life support system components are required when more than one EVA is conducted during a mission--the units are launched in an operational condition.

- Portable Life Support System (PLSS)
- Battery
- LiOH Cartridge
- Secondary Oxygen Pack (SOP)
- Control Assembly
- Oxygen for PLSS
- Oxygen for SOP
- Water for ALSA

Table 5-2 provides data for estimating the weight and volume costs of the EVA life support systems. Since the Orbiter will provide portable life support

systems for two EVA missions of two men each, the payload planner will be concerned only with LSS equipment exceeding Orbiter accommodations. The values quoted in the table are based on systems being considered in late 1974 for Space Shuttle application.

To use the table, the planner is required to:

1. Establish the <u>number of crewmen</u> required to be EVA to accomplish the payload tasks.
2. Establish the <u>number of EVAs</u> required to accomplish the payload tasks.

If item 1 or 2 above does not exceed a value of 2, the payload will not be charged with EVA life support equipment. If either item 1 or 2 exceeds a value of 2, continue to item 3.

3. Obtain required component weights and volumes by descending the selected column to the row of the individual item.
4. Establish the number of "Items" required based on 1 and 2 above.
5. Adjust component weights and volumes by multiplying the values given by the number of EVAs and crewmen required according to the "Items" and "Remarks" columns. Other adjustments may be required according to notes in the Remarks column. Record in "FOR USE BY PLANNER" column.
6. Obtain total weight and volume of Life Support Systems by scanning down the "FOR USE BY PLANNER" column and record in "FOR USE BY PLANNER--TOTALS column.

NOTE: If the number of crewmen required to perform EVA tasks does not exceed 2, and the total number of EVAs does not exceed 2, none of the costs in Table 5-2 will be charged to the payload.

TABLE 5-2: Astronaut Life Support Assembly (ALSA)

PARAMETER / LIFE SUPPORT SYSTEM HARDWARE	WEIGHT *		VOLUME *		FOR USE BY PLANNER		REMARKS	FOR USE BY PLANNER			
								TOTAL ITEM WEIGHT		TOTAL ITEM VOLUME	
	kg	lbs	cm^3	ft^3	NUMBER OF EVA CREWMEN REQUIRED	NUMBER OF ITEMS REQUIRED		kg	lbs	cm^3	ft^3
ASTRONAUT LIFE SUPPORT ASSEMBLY (ALSA)	65.5	144.4	82,130	2.9			TOTAL OPERATIONAL UNIT. 1 REQUIRED PER CREWMAN FEED WATER INCLUDED.				
• PORTABLE LIFE SUPPORT SYSTEM (PLSS)	37.6	82.8	62,300	2.2			CONTROL ASSEMBLY INCLUDED				
- BATTERY	4.4	9.8	5,660	.2			1 PER CREWMAN--RECHARGED AFTER EACH USE				
- LiOH CARTRIDGE	2.5	5.5	3,400	.12			1 PER CREWMAN PER EVA				
• SECONDAY OXYGEN PACK (SOP)	10.4	23.0	16,426	.58			1 PER CREWMAN				
• OXYGEN FOR PLSS	.72	1.6	--	--			RECHARGED EACH EVA FROM ORBITER				
• OXYGEN FOR SOP	1.82	4.0	--	--			INITIAL CHARGE ONLY				
• TRANSPORT WATER FOR ALSA	.54	1.2	--	--			INITIAL CHARGE ONLY				
• FEED WATER FOR ALSA	4.5	10.0	--	--			RECHARGED EACH EVA FROM ORBITER				
• SERVICING AND COOLING UMBILICAL	2.9	6.5	8,500	.3			1 PER ALSA UNIT				

*NOTE: Parameters are "best" estimates based on available Shuttle EVA information--December 1974.	FOR USE BY PLANNER TOTALS		

5.3 EVA SUPPORTING EQUIPMENT

In addition to the major systems (e.g., life support system, spacesuit), the EVA crewman may require a complement of equipment to support operations at a planned or unplanned worksite. Supporting equipment may include stabilization/restraint systems, tools, workstations, etc. Each EVA mission may require a different "set" of support hardware. The Shuttle Orbiter current payload accommodations (late 1974) do not provide EVA supporting equipment other than (proposed) mobility aids to access the aft payload bulkhead.

Portable-modular workstations with provisions to accommodate ancillary equipment such as lights, tool containers, and temporary stowage attachments appear to satisfy numerous payload servicing requirements. Portable workstations with connectors to interface with various worksite structural configurations may be developed to satisfy a wide range of crewman-to-payload restraint requirements (see Volumes I and II of this report). Systems of the above nature are not currently available for Shuttle EVA missions; however, preliminary studies have been conducted in many areas involving EVA support equipment. Spin-offs of these type studies may be incorporated into the Shuttle Orbiter EVA systems and should be closely followed by payload planners for application to their payloads/experiments.

Table 5-3 provides weight and volume data for estimating the impact of EVA supporting equipment to the payload. The "cost" estimates are given for the total workstation unit with a breakout of individual hardware items. The tripod workstation and the modular-portable workstation are assembled from components identified as requirements to support each payload EVA mission. The supporting equipment may be "packaged" and stowed for on-orbit placement or attached to the Orbiter payload bay or payload prior to launch.

To use the table:

1. Establish the number of crewmen required at the worksite(s) to accomplish the payload tasks.

2. Determine the number of each EVA supporting item required.
3. Obtain component weights and volumes by descending the equipment column to the row containing the required component.
4. Adjust component weights and volumes by multiplying the values given based on the number of EVA crewmen required and the "Items" and "Remarks" columns. Other adjustments may be required according to notes in the Remarks column. Record in "FOR USE BY PLANNER" column.
5. Obtain total weight and volume of EVA supporting equipment by scanning down the "FOR USE BY PLANNER" column and record in "FOR USE BY PLANNER--TOTALS" column.

NOTE: None of the items in Table 5-3 will be included in standard EVA Shuttle provisions. If required for payload tasks, these items will be charged to the payload.

TABLE 5-3: EVA Supporting Equipment

PARAMETER / EQUIPMENT ITEMS	WEIGHT*		VOLUME*		FOR USE BY PLANNER		REMARKS	FOR USE BY PLANNER			
					NUMBER OF EVA CREWMEN REQUIRED	NUMBER OF ITEMS REQUIRED		TOTAL ITEM WEIGHT		TOTAL ITEM VOLUME	
	kg	lbs	cm^3	ft^3				kg	lbs	cm^3	ft^3
TRIPOD WORKSTATION MODULAR-PORABLE	10.0	22.0	45,300	1.60			TOTAL WORKSTATION ASSEMBLY--STOWED				
• FOOT PLATE	2.3	5.0	6,230	.22			BASIC FOOT RESTRAINT				
• FOOT RESTRAINT ADAPTER	1.8	4.0	5,660	.20			TRIPOD MOUNTING UNIT				
• INGRESS AND STABILIZATION AIDS	2.0	4.5	4,250	.15			HANDRAIL/HANDHOLD FOR INGRESS/EGRESS				
• TOOL CONTAINER	2.0	4.5	8,500	.30			EXCLUDING TOOLS				
• PORTABLE LIGHT	1.4	3.0	2,830	.10							
• TEMPORARY STOWAGE ATTACHMENTS	.45	1.0	2,830	.10			FOR STOWING CARGO/MODULES AT WORKSITE				
WORKSTATION MODULAR-PORTABLE	11.3	25.0	62,300	2.2			TOTAL WORKSTATION ASSEMBLY--STOWED				
• BASE PLATE	2.5	5.5	6,800	.24			BASIC FOOT RESTRAINT				
• INGRESS RAILS	1.8	4.0	4,250	.15			HANDRAIL/HANDHOLD FOR INGRESS/EGRESS				
• TOOL CONTAINER	2.0	4.5	8,500	.30			EXCLUDING TOOLS				
• LIGHTS	1.4	3.0	2,830	.10							
• CAMERA MOUNT	.50	1.1	1,410	.05							
• EQUIPMENT HOOK	.64	1.4	1,410	.05			FOR TEMPORARY STOWAGE AT WORKSITE				
• TETHER	.22	.5	570	.02							
• ADAPTER PACKAGE	1.8	4.0	7,080	.25			FOR ATTACHING WORKSTATION TO VARIOUS WORKSITES				

TABLE 5-3: EVA Supporting Equipment (continued)

EQUIPMENT ITEMS \ PARAMETER	WEIGHT*		VOLUME*		FOR USE BY PLANNER		REMARKS	FOR USE BY PLANNER			
								TOTAL ITEM WEIGHT		TOTAL ITEM VOLUME	
	kg	lbs	cm^3	ft^3	NUMBER OF EVA CREWMEN REQUIRED	NUMBER OF ITEMS REQUIRED		kg	lbs	cm^3	ft^3
FOOT RESTRAINT	2.8	6.0	7,080	.25			FOOT RESTRAINTS ONLY MOUNTED PRIOR TO LAUNCH				
WRIST TETHER	.17	.38	280	.01			OPTIONAL				
WAIST TETHER	.23	.5	570	.02			OPTIONAL				
*NOTE: Parameters are "best" estimates based on available Shuttle information--December 1974.							FOR USE BY PLANNER TOTALS				

5.4 CREWMAN TRANSLATION AND CARGO TRANSFER AIDS

The crewman translation and cargo transfer systems with candidate applications on the Shuttle Orbiter and payloads were listed previously in Table 4-1, Section 4.0. Table 4-1 was prepared to aid the payload planner in defining qualified systems available for Space Shuttle use and as a guideline for selecting cargo transportation systems for payload EVA applications. Table 5-4 provides weight and volume data on each translation and cargo transfer unit/system for use in estimating EVA payload costs. The Shuttle Orbiter may provide (proposed mid-1974) crewman translation aids on the Orbiter forward (cabin) bulkhead, through the payload bay and on the aft bulkhead. One Shuttle remote manipulator system (RMS) will be provided for payload use and a second unit available at payload expense. Crewman translation aids and cargo transportation systems required outside those baselined as Shuttle payload accommodations must be provided by the payloads.

Both single and dual translation rails were used satisfactorily on previous space programs and represent an economical approach to crewman payload access when the payload is attached to the Orbiter. Extendible booms and clothesline cargo transfer systems were also used on the Skylab Program with good results. The Manned Maneuvering Unit (MMU) is currently the only candidate system that provides on-orbit crewman access to the entire Orbiter exterior or free-flying satellites.

To use the table:

1. Establish the number of EVA crewmen required to accomplish the payload tasks.
2. Determine the number of items required to support the payload EVA mission.
3. Obtain component weights and volumes by descending the equipment item column to the row containing the required hardware.

4. Adjust component weights and volumes by multiplying the values given based on the number of EVA crewmen required and the "Items" and "Remarks" columns. Other adjustments may be required according to notes in the Remarks column. Record in "FOR USE BY PLANNER" column.

5. Obtain total weight and volume of EVA supporting equipment by scanning down the "FOR USE BY PLANNER" column and record in "FOR USE BY PLANNER--TOTALS" column.

TABLE 5-4: Crewman Translation and Cargo Transfer Aids

EQUIPMENT ITEMS \ PARAMETER	WEIGHT *		VOLUME *		FOR USE BY PLANNER		REMARKS	FOR USE BY PLANNER			
	kg	lbs	cm^3	ft^3	NUMBER OF EVA CREWMEN REQUIRED	NUMBER OF ITEMS REQUIRED		TOTAL ITEM WEIGHT kg	TOTAL ITEM WEIGHT lbs	TOTAL ITEM VOLUME cm^3	TOTAL ITEM VOLUME ft^3
CREWMAN TRANSLATION AIDS											
SINGLE TRANSLATION RAIL	.14 kg/m	.3 lb/ft	930 cm^3/m	.01 ft^3/ft			INCLUDES MOUNTING HARDWARE (PER LINEAR UNIT)				
DUAL TRANSLATION RAIL	.28 kg/m	.6 lb/ft	1860 cm^3/m	.02 ft^3/ft			INCLUDES MOUNTING HARDWARE (PER LINEAR UNIT)				
HANDHOLDS	.27	.60	2,270	.08			INCLUDES MOUNTING PROVISIONS				
MANNED MANEUVERING UNIT (MMU)	74.8	165	--	--			UNIT IN PRELIMINARY DESIGN--DECEMBER 1974				
• MMU SUPPORT EQUIPMENT	49.9	110	--	--			INCLUDES PROPELLANT SERVICING HARDWARE/PROVISIONS, ETC.				
PLANNER CALCULATIONS											
CARGO TRANSFER AIDS											
EXTENDIBLE BOOM	40.6	89.5	76,464	2.7			UNIT USED ON SKYLAB PROGRAM				
CLOTHESLINE SYSTEM	--	$\geq$8.0	8,500	.3			UNIT USED ON SKYLAB PROGRAM				
REMOTE MANIPULATOR SYSTEM (RMS)	403.6	890.0	--	--			STOWAGE VOLUME SUPPLIED BY ORBITER				
*NOTE: Parameters are "best" estimates based on available Shuttle information--December 1974.							FOR USE BY PLANNER TOTALS ➧				

5.5 TOOL LIST

Experience from previous orbital EVA missions has indicated that when properly restrained, the crewman can perform most of the manipulative operations he can perform in an earth environment. (Glove encumbrance, of course, affects handling very small items.) Many EVA tasks on past missions have been accomplished using off-the-shelf industrial or consumer tools with minor modifications to enhance handling/gripping and tether provisions to prevent loss.

Given proper interface designs (i.e., designing payloads for EVA servicing), a variety of hand tools may satisfy the payload servicing requirements. Several special "zero" and reduced-reaction power tools were developed and evaluated for use on previous space programs. However, mission conditions did not require use of the special units other than in a space-qualifying capacity.

A representative small tools listing is provided in Table 5-5 to assist in estimating the weight and volume cost to the payload. Many of the tools listed in the table are of the types used on previous orbital missions or for Skylab intravehicular maintenance--others were based on general mechanical maintenance interfaces. The weights and volumes were obtained from stowage lists of previous space programs, where available, and others derived from consumer products. Powered and special application tools are not included in the listing.

Sufficient space is provided in the table for listing of dedicated tools. Each EVA man-system interface task must be studied by the planner to determine the following: (1) are tools required, (2) are off-the-shelf tools adequate, and (3) if special power tools are required, can existing units be used to reduce research and development costs. A description of power tools developed for the space programs can be obtained from reference 12.

Using Table 5-5 requires only that the planner identify the type and quantity of tools needed, and record the total in the space provided. The

Shuttle Orbiter may provide a general maintenance tool kit. However, the contents were not identified during development of the EVA Cost Model. Consequently, only those tools needed for payload servicing should be considered a payload penalty.

TABLE 5-5: Tool List

PARAMETER / TOOL ITEM		WEIGHT		VOLUME *		FOR USE BY PLANNER	REMARKS	FOR USE BY PLANNER			
						NUMBER OF ITEMS REQUIRED		TOTAL ITEM WEIGHT		TOTAL ITEM VOLUME	
		kg	lbs	cm³	in³			kg	lbs	cm³	in³
SCREWDRIVING AND TORQUING TOOLS											
WRENCH, CRESCENT	15.2 cm. (6 in.)	.15	.32	73.8	4.5						
	20.3 cm. (8 in.)	.15	.32	98.3	6.0						
	25.4 cm. (10 in.)	.15	.34	163.9	10.0						
WRENCH, SOCKET SET	6 pc. set	.57	1.26	901.5	55.0						
	8 pc. set	.70	1.55	1311.2	80.0						
	10 pc. set	.82	1.80	1557.1	95.0						
PLIERS	slip joint	.15	.33	98.3	6.0						
	connector	.15	.32	98.3	6.0						
	needlenose	.15	.32	98.3	6.0						
	channel lock	.15	.33	114.7	7.0						
	vise grip	.15	.34	131.1	8.0						
*estimated from general consumer products							FOR USE BY PLANNER TOTAL				

TABLE 5-5: Tool List (continued)

TOOL ITEM \ PARAMETER		WEIGHT kg	WEIGHT lbs	VOLUME * cm³	VOLUME * in³	FOR USE BY PLANNER: NUMBER OF ITEMS REQUIRED	REMARKS	FOR USE BY PLANNER: TOTAL ITEM WEIGHT kg	TOTAL ITEM WEIGHT lbs	TOTAL ITEM VOLUME cm³	TOTAL ITEM VOLUME in³
SCREWDRIVING AND TORQUING TOOLS (cont'd.)											
SCREWDRIVERS (STANDARD OR PHILLIPS)	10.2 cm. (4 in.)	.08	.17	73.8	4.5						
	15.2 cm. (6 in.)	.10	.22	111.5	6.8						
	20.3 cm. (8 in.)	.13	.28	147.5	9.0						
	25.4 cm. (10 in.)	.15	.34	185.2	11.3						
	30.5 cm. (12 in.)	.17	.38	222.9	13.6						
WRENCH, OPEN/BOX END	5 pc. set	1.0	2.2	358.9	21.9						
	7 pc. set	1.5	3.2	519.6	31.7						
	9 pc. set	2.0	4.5	104.2	63.6						
ALLEN WRENCHES	3 pc. set	.11	.25	29.5	1.8						
	5 pc. set	.18	.40	63.9	3.9						
	7 pc. set	.27	.60	108.7	6.6						
*estimated from general consumer products							FOR USE BY PLANNER: TOTAL				

TABLE 5-5: Tool List (continued)

TOOL ITEM	PARAMETER	WEIGHT kg	WEIGHT lbs	VOLUME* cm^3	VOLUME* in^3	FOR USE BY PLANNER NUMBER OF ITEMS REQUIRED	REMARKS	FOR USE BY PLANNER TOTAL ITEM WEIGHT kg	FOR USE BY PLANNER TOTAL ITEM WEIGHT lbs	FOR USE BY PLANNER TOTAL ITEM VOLUME cm^3	FOR USE BY PLANNER TOTAL ITEM VOLUME in^3
SCREWDRIVING AND TORQUING TOOLS (cont'd.)											
PRY BAR	.76 m. (30 in.)	.68	1.50	386.8	23.6						
IMPACT TOOLS											
HAMMER AND MALLET	BALL PEEN	.27	.60	327.8	20.0						
	MALLET	.18	.40	401.6	24.5						
CUTTING TOOLS											
DIAGONAL CUTTER, 20.3 cm. (8 in.)		.15	.33	98.3	6.0						
SCISSOR		.07	.16	65.6	4.0						
KNIFE		.23	.50	31.1	1.9						
WIRE STRIPPER		.07	.16	82.0	5.0						
BOLT CUTTER		2.90	6.39	603.2	36.8						
CABLE CUTTER		3.29	7.25	645.8	39.4						
*estimated from general consumer products							FOR USE BY PLANNER TOTAL				

5.6 ORBITER "OPTIONAL" CONFIGURATION HARDWARE

Several Orbiter configurations relative to airlock location are currently being studied for accommodating the various payloads. An EVA egress module for use with on-orbit habitable Spacelabs is also being considered. The payload community may have an "option" in configuring the Orbiter payload bay relative to airlock location, when EVA is required. Three configuration alternatives being considered by NASA are:

- Capability to remove and install the baseline airlock (located inside Shuttle cabin) in the payload bay
- Capability to install a second airlock in the payload bay to allow shirtsleeve access to a Spacelab module during EVA missions
- Capability to utilize an EVA egress module in conjunction with the baseline airlock to allow EVA access when a Spacelab module is flown

The cost allocation to the Orbiter and payloads for the options being studied has not been determined. An airlock may not be available on each Shuttle flight since rescue can be accomplished from the Orbiter side hatch by depressurizing the cabin. Should the payloads be assessed with the cost of optional configuration hardware, Table 5-6 will allow estimates to be made of the weight, volume and expendables. The expendables (O_2, N_2) will be charged to the payload for all airlock (or EVA egress module) repressurization in excess of two per Shuttle mission. Using Table 5-6 requires only that the planner identify the optional equipment required and number of repressurizations (above two) and record the calculated totals in the space provided.

TABLE 5-6: Orbiter "Optional" Configuration Hardware

ITEM EQUIPMENT \ PARAMETER	WEIGHT*		VOLUME*		FOR USE BY PLANNER	REMARKS	FOR USE BY PLANNER			
					NUMBER OF REPRESS. REQUIRED		TOTAL ITEM WEIGHT		TOTAL ITEM VOLUME	
	kg	lbs	m^3	ft^3			kg	lbs	m^3	ft^3
AIRLOCK REPRESS.										
• OXYGEN	1.2	2.7	--	--		PROVIDED FROM ORBITER TANKAGE				
• NITROGEN	3.9	8.5	--	--		PROVIDED FROM ORBITER TANKAGE				
EGRESS MODULE**	394.6	870.0	3.40	120		UNDER STUDY--DECEMBER 1974				
• OXYGEN	1.0	2.2	--	--		PROVIDED FROM ORBITER TANKAGE				
• NITROGEN	3.1	6.8	--	--		PROVIDED FROM ORBITER TANKAGE				
						FOR USE BY PLANNER — TOTALS ➧				

*NOTE: Parameters are "best" estimates based on available Shuttle EVA information--December 1974.

**Proposed for EVA capability for manned payload interface to Orbiter.

A summary chart/master worksheet (Table 6-1) is provided to allow the user to systematically record the estimated cost of EVA as the model is being used. Each of the major costs in terms of weight, volume, crew time, etc. can be summarized individually on the master worksheets. The individual worksheets (Appendix B) may also be used as a checklist for identifying a complement of necessary EVA systems/hardware.

The EVA tasks and number of EVAs needed are identified from the payload requirements. These requirements are compared to the EVA crewman's capabilities from the information contained in Section 2.0 of this report and other pertinent documentation. From the capabilities information the number of EVA crewmen required, the EVA duration, and the EVA equipment needed are estimated. The individual EVA equipment Cost Model sheets are then used to estimate the cost of each item or operation associated with EVA.

The EVA time (i.e., the total amount of time required to perform the tasks and translate to and from the worksite) must be estimated. This time is then added to the pre- and post-EVA times to derive a total EVA crew time estimate.

TABLE 6-1: EVA Cost Summary Worksheet

PAYLOAD NAME ________________________________

PAYLOAD NO. ____________ TASK DESCRIPTION ____________________

NUMBER CREWMEN REQUIRED ______ ESTIMATED TASK DURATION (HRS.) ______ NUMBER OF EVAs ______

COST ELEMENT	WEIGHT		VOLUME		REMARKS
	kg	lbs	m^3	ft^3	
SPACE SUIT ASSEMBLY					
COMPONENTS-HARDWARE					
LIFE SUPPORT SYSTEM					
COMPONENTS-HARDWARE					
EVA WORKSTATION					
ANCILLARY EQUIPMENT					
CREWMAN TRANSFER AIDS					
CARGO TRANSFER AIDS					

TABLE 6-1: EVA Cost Summary Worksheet (continued)

COST ELEMENT	WEIGHT		VOLUME		REMARKS
	kg	lbs	m^3	ft^3	
TOOLS					
"OPTIONAL" HARDWARE					
MISCELLANEOUS EVA ITEMS					

TOTAL EVA COST	WEIGHT: ________ (kg) ________ (lbs)	VOLUME: ________ (m^3) ________ (ft^3)	CREW TIME: ______ (hrs)

NOTES/CALCULATIONS

REFERENCES

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11. Covington, John H. (Preliminary Information for Space Shuttle EVA Preparation and Post EVA Functions), NASA-Johnson Space Center, Flight Operations Directorate, Crew Training and Procedures Division.

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APPENDIX A

EVA MISSION COST EXAMPLE

APPENDIX A

EVA MISSION COST EXAMPLE

An EVA mission example is presently based on a revisit to both the Extended X-Ray Survey satellite (HE-03-A) and the Large High Energy Observatory D (HE-11-A) on a single Shuttle mission of 7 days. Both the HE-03-A and HE-11-A are scheduled for revisits in 1985 for servicing and/or refurbishment. The circular orbits are separated by 93 km (50 mi.), and the desired inclinations are 28 deg. for HE-03-R and 15 deg. for HE-11-R. The revisits may be conducted on a shared (piggy-back) basis with other missions having compatible orbits and inclinations. Both payloads currently specify 3 EVA missions of 4 hours duration each for servicing operations. The total EVA for the combined EVA operations would be 6 missions of 4 hours duration each or 24 total EVA-hours outside the Orbiter cabin.

The EVA example is considered an ambitious program but was devised to show the relative low cost of providing an EVA capability for payload support. In developing the scenario, the following guidelines and assumptions were used:

- The payloads will be berthed in the Orbiter for servicing.
- The Orbiter will provide equipment and accommodations for two 2-man EVAs of 6 hours each.
- The payloads will be charged for all EVA chargeable provisions in excess of the above.
- Two EVA crewmen will be required outside the Orbiter throughout the EVA mission.
- The EVA missions can be completed in one 7-day Shuttle flight.
- The EVA tasks are considered "severe" relative to suit usage.
- Sufficient spares are provided to assure that mission success will not be impaired by equipment malfunction/failure.
- An EVA workstation will be required at two worksites.
- EVA crewmen may perform non-related EVA tasks during prebreathing.

The EVA Systems Cost Model is exercised using the methodology derived in this report. Appropriate worksheets were completed and are provided in this appendix.

CONCLUSIONS

The EVA mission (example) can be accomplished with a cost in weight and volume of approximately 163 kg. (360 lbs.) and .4 m^3 (14 ft^3), respectively. The total crew time would be approximately 114 man-hours assuming two EVA crewmen participating in the operations and a payload specialist monitoring EVA operations for 24 hours. Prebreathing time is not included in the total man-hours. The weight of 163 kg. (360 lbs.) is 9.0% of the total 8,800 kg. (4,000 lbs.) required for servicing/refurbishment. Converting the cost of an EVA capability to a dollar value cannot be accomplished at this time since the strategy and procedures for charging Shuttle users have not been determined by NASA. The current NASA agency target cost estimate per Shuttle flight is 10.45 million dollars. However, the charge to any given payload will not be $10.45 million. If the procedure for charging payloads is a function of weight, volume and time on-orbit, EVA charges can easily be calculated by the EVA Systems Cost Model user.

EVA MISSION TIME WORKSHEET

PRE-EVA FUNCTION	CREW TIME (min.)	REMARKS/EXPLANATION
START PREBREATHE	5	Prebreathing equipment (rebreather, O_2 umbilical, and mask) is unstowed, connected and operationally checked. Crewman starts prebreathing and continues for up to 2 hours until the scheduled start of EVA preparation activities. During this 2-hour period, the crewman may perform required non-EVA related activities.
	START EVA PREPARATION	
CABIN PREPARATION	10	Airlock and lower deck area are configured for life support equipment and suit donning. Donning aids, such as restraint devices and temporary stowage compartments, are unstowed and positioned, as required.
EQUIPMENT PREPARATION	15	Equipment required for EVA (i.e., suits, life support equipment, tethers, etc.) are unstowed and positioned for donning. Preliminary checkout of the equipment will be performed, as required.
SUIT DONNING	30	Inflight suits are doffed and stowed. EVA and ancillary equipment (i.e., crewman's waste management system and liquid cooling garment) are donned. Crewman connects to the airlock water cooling umbilicals.
ALSA DONNING	15	Life support equipment (backpack) donning would be completed if an integrated EMU is provided.
HELMET/GLOVE DONNING	15	After completion of prebreathe, crewman will doff the rebreather and don comm carrier, helmet and gloves. O_2 purge of EMU will then be performed.

EVA MISSION TIME (CONTINUED)

PRE-EVA FUNCTION	CREW TIME (min.)	REMARKS/EXPLANATION
COMMUNICATION CHECK	10	Comm check between the ALSAs and the Orbiter comm system is made. ALSA telemetry is checked. Backup ALSA comm modes are also checked.
INTEGRITY CHECK	5	An integrity check of the EMUs is performed prior to completion of airlock depress. This is a gross check of the EMU to verify that all connections are made and that leakage is acceptable
AIRLOCK DEPRESS	6	Airlock depress will be performed by the EVA crewman. Depress will be interrupted at least once to verify EMU and airlock integrity.
HATCH OPENING	4	After opening and securing outer airlock hatch, the crew will initiate start-up of ALSA cooling. After cooling has been established, crew will begin the EVA.
SUBTOTAL	110	EVA preparation only
FOR USE BY PLANNER		
EVA MISSION OPERATIONS TIME ESTIMATE	240	• ONE FOUR HOUR EVA ONLY

POST-EVA FUNCTIONS	CREW TIME (min.)	REMARKS/EXPLANATION
HATCH CLOSING	5	After completion of EVA, crewman ingresses the airlock; ALSA cooling is shut down and outer airlock hatch closed.
AIRLOCK REPRESS	5	Crewman represses airlock and verifies airlock integrity.

EVA MISSION TIME (CONTINUED)

POST-EVA FUNCTIONS	CREW TIME (min.)	REMARKS/EXPLANATION
HELMET/GLOVE DOFFING	10	After suit pressure is equalized with ambient, crewman doffs and stows helmet and gloves and connects to the Orbiter water cooling system. The ALSA is deactivated.
ALSA DOFFING	15	ALSA is doffed and secured in the airlock. If integrated EMU is used, ALSA is doffed with the suit.
SUIT DOFFING	30	ALSA and suit are doffed and secured if an integrated EMU is used. Otherwise, suit is doffed during this period. Crewman also doffs ancillary suit equipment and dons flight suit. Suits and ancillary equipment are stowed unless suit drying is required.
ALSA RECHARGE	20	ALSA consumables are replaced during this period. ALSA is prepared and secured for next EVA. Loose equipment, such as tethers and cameras, is stowed.
SUIT DRYING	20	Suit drying is initiated, if required. If not required, suits and ancillary equipment are stowed, and the lower deck area/airlock are returned to pre-EVA configuration.
FOR USE BY PLANNER		
TOTAL	455 (≈7.5hrs)	• TOTAL FOR SIX FOUR-HOUR EVA'S WOULD BE ≈45 HOURS PER EVA CREWMAN OR 90 MAN-HOURS. ADD 24 MAN-HOURS FOR EVA MONITORING IN FINAL ANALYSIS.

NOTE: Timeline and sequences outlined are typical of those required for Shuttle EVA preparation and post-EVA activities. They are subject to change as equipment required to support EVA is better defined and procedures are optimized.

CREWMAN AND CARGO TRANSFER SYSTEM SELECTION

CARGO TRANSFER AIDS	CARGO MASS AND VOLUME							REMARKS/APPLICATIONS
	CREWMAN ONLY	CLASS I		CLASS II		CLASS III		
		SI	CONV.	SI	CONV.	SI	CONV.	
	NO CARGO	<73 kg. and <.3 m^3	<160 lbs. and <10 ft^3	73-730 kg. and .3-3.9 m^3	160-1600 lbs. and 10-40 ft^3	>730 kg. and >3.9 m^3	>1600 lbs. and >40 ft^3	
NO AIDS	yes	no		no		no		IVA ONLY--SHORT DISTANCES FREE FLOATING
VEHICLE EQUIPMENT	yes	yes		no		no		EXISTING VEHICLE EQUIPMENT ALONG TRANSLATION ROUTE OTHER THAN TRANSLATION AIDS
HANDHOLDS	yes	yes		no		no		PACKAGE TETHERED TO CREWMAN DURING TRANSFER
SINGLE TRANSLATION RAIL	yes	yes		no		no		USED ON SKYLAB--PACKAGE HANDHELD AND TETHERED TO CREWMAN
DUAL TRANSLATION RAIL	yes	yes		yes		no		USED ON SKYLAB--RATED HIGHLY BY CREWMEN
CLOTHESLINE SYSTEM	yes	yes		yes		no		MANUALLY ACTUATED ON SKYLAB
EXTENDIBLE BOOM	no	yes		yes		no		ELECTRICALLY ACTUATED CARGO BOOM
SHUTTLE MANIPULATOR ARMS	no	yes		yes		yes		REMOTELY ACTUATED FROM SHUTTLE CABIN
MANNED MANEUVERING UNIT	yes	yes		yes		requires study		PACKAGE ATTACHED TO MMU FOR FREE SPACE TRANSFER

SPACESUIT AND SUPPORT HARDWARE WORKSHEET

SPACE SUIT ITEMS \ PARAMETER	WEIGHT kg	WEIGHT lbs	VOLUME cm^3	VOLUME ft^3	FOR USE BY PLANNER: NUMBER OF EVA CREWMEN REQUIRED	FOR USE BY PLANNER: NUMBER OF ITEMS REQUIRED	REMARKS	FOR USE BY PLANNER: TOTAL ITEM WEIGHT kg	TOTAL ITEM WEIGHT lbs	TOTAL ITEM VOLUME cm^3	TOTAL ITEM VOLUME ft^3
TOTAL SPACE SUIT ASSEMBLY	31.2	68.8	TBD	TBD			1 REQUIRED PER CREWMAN--INCLUDES ALL ITEMS LISTED BELOW EXCEPT: (1) CREW PROVISIONS; AND (2) FLIGHT CREW EQUIPMENT				
• INTEGRATED TORSO LIMB SUIT ASSEMBLY	21.8	48.0	123,912	4.35			1 PER CREWMAN				
• LIQUID COOLING GARMENT (LCG)	1.6	3.6	7,080	.25	2	2	1 PER CREWMAN	3.3	7.2	14,160	.5
• HELMET	1.4	3.0	28,320	1.0	2	1	1 PER CREWMAN	1.4	3.0	28,320	1.0
• EXTRAVEHICULAR VISOR ASSEMBLY (EVVA)	2.37	5.0	19,824	.70			1 PER CREWMAN				
• EV GLOVES	1.4	3.0	1,982	.07	2	2 PR	1 PAIR PER CREWMAN	2.7	6.0	2,832	.1
• COMMUNICATION CARRIER ASSEMBLY (CCA)	.73	1.6	--	--	2	1	1 PER CREWMAN	.7	1.6	--	--
• IN-SUIT DRINKING DEVICE	.18	.4	2,832	.10	2	8	1 PER CREWMAN PER EVA	1.4	3.2	28,320	1.0
• URINE COLLECTION DEVICE	.18	.4	5,664	.20	2	8	1 PER CREWMAN PER EVA	1.4	3.2	56,640	2.0
• WATER FOR LCG	.45	1.0	--	--			INITIAL CHARGE ONLY				
• PERSONAL RADIATION DOSIMETER	.04	.1	85	.003			1 PER CREWMAN				
• PASSIVE RADIATION DOSIMETER	.04	.1	85	.003			1 PER CREWMAN				
• WRIST TETHER "D" RING	.14	.3	--	--			NONE REQUIRED--IS TASK DEPENDENT				
• IN-SUIT ELECTRICAL HARNESS	.18	.4	--	--	2	1	1 PER CREWMAN	.2	.4	--	--
• BIOINSTRUMENTATION SYSTEM	.86	1.9	850	.03	2	1	1 PER CREWMAN	.8	1.9	--	--

SPACESUIT AND SUPPORT HARDWARE WORKSHEET (CONTINUED)

SPACE SUIT HARDWARE / PARAMETER	WEIGHT kg	WEIGHT lbs	VOLUME cm^3	VOLUME ft^3	FOR USE BY PLANNER: NUMBER OF EVA CREWMEN REQUIRED	FOR USE BY PLANNER: NUMBER OF ITEMS REQUIRED	REMARKS	FOR USE BY PLANNER: TOTAL ITEM WEIGHT kg	TOTAL ITEM WEIGHT lbs	TOTAL ITEM VOLUME cm^3	TOTAL ITEM VOLUME ft^3
CREW PROVISIONS	.68	1.5	850	.03			OPERATION OPTION--NOT INCLUDED IN SPACESUIT ASSEMBLY				
• COMFORT GLOVES	.04	.1	283	.01	2	2	OPTIONAL	.1	.20	566	.020
• WATCHBAND	.01	.02	283	.01			OPTIONAL				
• CHRONOGRAPH	.06	.13	283	.01			TASK DEPENDENT				
FLIGHT CREW EQUIPMENT	.65	1.34	736	.026			OPERATION OPTION--NOT INCLUDED IN SPACESUIT ASSEMBLY				
• PEN LIGHT	.17	.38	57	.002	2	2	TASK DEPENDENT	.3	.76	113	.004
• PENCIL	.02	.05	28	.001	2	1	TASK DEPENDENT	--	.05	28	.001
• MARKER PEN	.01	.03	28	.001	2	1	TASK DEPENDENT	--	.03	28	.001
• POUCH, SWISS ARMY KNIFE	.02	.05	28	.001	2	1	OPTIONAL	--	.05	28	.001
• POCKET ASSY., SCISSORS	.04	.08	28	.001	2	1	OPTIONAL	--	.08	28	.001
• POCKET ASSY., CHECKLIST	.19	.42	280	.010	2	2	TASK DEPENDENT	.4	.84	566	.020
• DATA LIST	.15	.33	280	.010			TASK DEPENDENT				
							FOR USE BY PLANNER — TOTALS ➧	13.0	28.5	130,220	4.7

EVA LIFE SUPPORT SYSTEM WORKSHEET

PARAMETER / LIFE SUPPORT SYSTEM HARDWARE	WEIGHT *		VOLUME *		FOR USE BY PLANNER		REMARKS	FOR USE BY PLANNER			
					NUMBER OF EVA CREWMEN REQUIRED	NUMBER OF ITEMS REQUIRED		TOTAL ITEM WEIGHT		TOTAL ITEM VOLUME	
	kg	lbs	cm^3	ft^3				kg	lbs	cm^3	ft^3
ASTRONAUT LIFE SUPPORT ASSEMBLY (ALSA)	65.5	144.4	82,130	2.9			TOTAL OPERATIONAL UNIT. 1 REQUIRED PER CREWMAN FEED WATER INCLUDED.				
• PORTABLE LIFE SUPPORT SYSTEM (PLSS)	37.6	82.8	62,300	2.2			CONTROL ASSEMBLY INCLUDED				
- BATTERY	4.4	9.8	5,660	.2	2	2	1 PER CREWMAN--RECHARGED AFTER EACH USE	8.9	19.6	11,330	.4
- LiOH CARTRIDGE	2.5	5.5	3,400	.12	2	9	1 PER CREWMAN PER EVA	22.5	49.5	31,150	1.1
• SECONDAY OXYGEN PACK (SOP)	10.4	23.0	16,426	.58			1 PER CREWMAN				
• OXYGEN FOR PLSS	.72	1.6	--	--	2	9	RECHARGED EACH EVA FROM ORBITER	6.5	14.4	--	--
• OXYGEN FOR SOP	1.82	4.0	--	--	2	1	INITIAL CHARGE ONLY	1.8	4.1	--	--
• TRANSPORT WATER FOR ALSA	.54	1.2	--	--			INITIAL CHARGE ONLY				
• FEED WATER FOR ALSA	4.5	10.0	--	--	2	8	RECHARGED EACH EVA FROM ORBITER	36.3	80.0	--	--
• SERVICING AND COOLING UMBILICAL	2.9	6.5	8,500	.3			1 PER ALSA UNIT				
*NOTE: Parameters are "best" estimates based on available Shuttle EVA information--December 1974.							FOR USE BY PLANNER TOTALS ➧	76.0	167.5	42,480	1.5

EVA SUPPORTING EQUIPMENT WORKSHEET

EQUIPMENT ITEMS / PARAMETER	WEIGHT*		VOLUME*		FOR USE BY PLANNER		REMARKS	FOR USE BY PLANNER			
								TOTAL ITEM WEIGHT		TOTAL ITEM VOLUME	
	kg	lbs	cm^3	ft^3	NUMBER OF EVA CREWMEN REQUIRED	NUMBER OF ITEMS REQUIRED		kg	lbs	cm^3	ft^3
TRIPOD WORKSTATION	10.0	22.0	45,300	1.60			TOTAL WORKSTATION ASSEMBLY--STOWED				
• FOOT PLATE	2.3	5.0	6,230	.22			BASIC FOOT RESTRAINT				
• FOOT RESTRAINT ADAPTER	1.8	4.0	5,660	.20			TRIPOD MOUNTING UNIT				
• INGRESS AND STABILIZATION AIDS	2.0	4.5	4,250	.15			HANDRAIL/HANDHOLD FOR INGRESS/EGRESS				
• TOOL CONTAINER	2.0	4.5	8,500	.30			EXCLUDING TOOLS				
• PORTABLE LIGHT	1.4	3.0	2,830	.10							
• TEMPORARY STOWAGE ATTACHMENTS	.45	1.0	2,830	.10			FOR STOWING CARGO/MODULES AT WORKSITE				
WORKSTATION MODULAR-PORTABLE	11.3	25.0	62,300	2.2	2	2	TOTAL WORKSTATION ASSEMBLY--STOWED	22.7	50.0	124,600	4.40
• BASE PLATE	2.5	5.5	6,800	.24			BASIC FOOT RESTRAINT				
• INGRESS RAILS	1.8	4.0	4,250	.15			HANDRAIL/HANDHOLD FOR INGRESS/EGRESS				
• TOOL CONTAINER	2.0	4.5	8,500	.30	2	1	EXCLUDING TOOLS	2.4	4.5	8,500	.30
• LIGHTS	1.4	3.0	2,830	.10	2	1		1.4	3.0	2,830	.10
• CAMERA MOUNT	.50	1.1	1,410	.05							
• EQUIPMENT HOOK	.64	1.4	1,410	.05	2	2	FOR TEMPORARY STOWAGE AT WORKSITE	1.3	2.8	2,830	.10
• TETHER	.22	.5	570	.02	2	2		.4	1.0	1,133	.04
• ADAPTER PACKAGE	1.8	4.0	7,080	.25	2	1	FOR ATTACHING WORKSTATION TO VARIOUS WORKSITES	1.8	4.0	7,080	.25

EVA SUPPORTING EQUIPMENT WORKSHEET (CONTINUED)

EQUIPMENT ITEMS \ PARAMETER	WEIGHT* kg	WEIGHT* lbs	VOLUME* cm^3	VOLUME* ft^3	FOR USE BY PLANNER: NUMBER OF EVA CREWMEN REQUIRED	FOR USE BY PLANNER: NUMBER OF ITEMS REQUIRED	REMARKS	FOR USE BY PLANNER: TOTAL ITEM WEIGHT kg	TOTAL ITEM WEIGHT lbs	TOTAL ITEM VOLUME cm^3	TOTAL ITEM VOLUME ft^3
FOOT RESTRAINT	2.8	6.0	7,080	.25	2	1	FOOT RESTRAINTS ONLY MOUNTED PRIOR TO LAUNCH	2.7	6.0	7,080	.25
WRIST TETHER	.17	.38	280	.01	2	2	OPTIONAL	.3	0.8	570	.02
WAIST TETHER	.23	.5	570	.02	2	2	OPTIONAL	.4	1.0	1,133	.04
							FOR USE BY PLANNER: TOTALS	33.2	73.1	155,760	5.50

*NOTE: Parameters are "best" estimates based on available Shuttle information--December 1974.

CREWMAN TRANSLATION AND CARGO TRANSFER AIDS WORKSHEET

EQUIPMENT ITEMS \ PARAMETER	WEIGHT * kg	WEIGHT * lbs	VOLUME * cm^3	VOLUME * ft^3	FOR USE BY PLANNER: NUMBER OF EVA CREWMEN REQUIRED	FOR USE BY PLANNER: NUMBER OF ITEMS REQUIRED	REMARKS	FOR USE BY PLANNER: TOTAL ITEM WEIGHT kg	TOTAL ITEM WEIGHT lbs	TOTAL ITEM VOLUME cm^3	TOTAL ITEM VOLUME ft^3
CREWMAN TRANSLATION AIDS											
SINGLE TRANSLATION RAIL	.14 kg/m	.3 lb/ft	930 cm^3/m	.01 ft^3/ft	2	60ft	INCLUDES MOUNTING HARDWARE (PER LINEAR UNIT)	8.2	18.0	16,990	.60
DUAL TRANSLATION RAIL	.28 kg/m	.6 lb/ft	1860 cm^3/m	.02 ft^3/ft			INCLUDES MOUNTING HARDWARE (PER LINEAR UNIT)				
HANDHOLDS	.27	.60	2,270	.08	2	60ft	INCLUDES MOUNTING PROVISIONS	1.6	3.6	13,600	.48
MANNED MANEUVERING UNIT (MMU)	74.8	165	--	--			UNIT IN PRELIMINARY DESIGN--DECEMBER 1974				
• MMU SUPPORT EQUIPMENT	49.9	110	--	--			INCLUDES PROPELLANT SERVICING HARDWARE/PROVISIONS, ETC.				
PLANNER CALCULATIONS											
CARGO TRANSFER AIDS											
EXTENDIBLE BOOM	40.6	89.5	76,464	2.7			UNIT USED ON SKYLAB PROGRAM				
CLOTHESLINE SYSTEM	--	≥8.0	8,500	.3	2	1	UNIT USED ON SKYLAB PROGRAM	3.6	8.0	8,500	.30
REMOTE MANIPULATOR SYSTEM (RMS)	403.6	890.0	--	--			STOWAGE VOLUME SUPPLIED BY ORBITER				
							FOR USE BY PLANNER — TOTALS ➧	13.4	29.6	39,080	1.38

*NOTE: Parameters are "best" estimates based on available Shuttle information--December 1974.

TOOL REQUIREMENTS WORKSHEET

TOOL ITEM / PARAMETER		WEIGHT kg	WEIGHT lbs	VOLUME* cm³	VOLUME* in³	FOR USE BY PLANNER: NUMBER OF ITEMS REQUIRED	REMARKS	FOR USE BY PLANNER: TOTAL ITEM WEIGHT kg	TOTAL ITEM WEIGHT lbs	TOTAL ITEM VOLUME cm³	TOTAL ITEM VOLUME in³
SCREWDRIVING AND TORQUING TOOLS											
WRENCH, CRESCENT	15.2 cm. (6 in.)	.15	.32	73.8	4.5						
	20.3 cm. (8 in.)	.15	.32	98.3	6.0	1		.1	.32	98	6.0
	25.4 cm. (10 in.)	.15	.34	163.9	10.0						
WRENCH, SOCKET SET	6 pc. set	.57	1.26	901.5	55.0						
	8 pc. set	.70	1.55	1311.2	80.0						
	10 pc. set	.82	1.80	1557.1	95.0	1		.8	1.80	1,577	95.0
PLIERS	slip joint	.15	.33	98.3	6.0	1		.1	.33	98	6.0
	connector	.15	.32	98.3	6.0	1		.1	.32	98	6.0
	needlenose	.15	.32	98.3	6.0						
	channel lock	.15	.33	114.7	7.0	1		.1	.33	115	7.0
	vise grip	.15	.34	131.1	8.0	2		.3	.68	262	16.0
*estimated from general consumer products							FOR USE BY PLANNER: TOTAL ➧	1.7	380	2229	136.0
								UNIT CONVERSIONS		m³: .0022	ft³: .08

TOOL REQUIREMENTS WORKSHEET (CONTINUED)

TOOL ITEM \ PARAMETER		WEIGHT		VOLUME *		FOR USE BY PLANNER	REMARKS	FOR USE BY PLANNER			
								TOTAL ITEM WEIGHT		TOTAL ITEM VOLUME	
		kg	lbs	cm³	in³	NUMBER OF ITEMS REQUIRED		kg	lbs	cm³	in³
SCREWDRIVING AND TORQUING TOOLS (cont'd.)											
SCREWDRIVERS (STANDARD OR PHILLIPS)	10.2 cm. (4 in.)	.08	.17	73.8	4.5						
	15.2 cm. (6 in.)	.10	.22	111.5	6.8	2		.2	.44	207	12.6
	20.3 cm. (8 in.)	.13	.28	147.5	9.0						
	25.4 cm. (10 in.)	.15	.34	185.2	11.3	2		.3	.68	370	22.6
	30.5 cm. (12 in.)	.17	.38	222.9	13.6						
WRENCH, OPEN/BOX END	5 pc. set	1.0	2.2	358.9	21.9						
	7 pc. set	1.5	3.2	519.6	31.7						
	9 pc. set	2.0	4.5	104.2	63.6	1		.2	.45	1042	63.6
ALLEN WRENCHES	3 pc. set	.11	.25	29.5	1.8						
	5 pc. set	.18	.40	63.9	3.9						
	7 pc. set	.27	.60	108.7	6.6	1		.3	.60	108	6.6
*estimated from general consumer products							FOR USE BY PLANNER TOTAL ➧	1.0	2.2	1,727	105.4
								UNIT CONVERSIONS		in³	ft³
										.0017	.06

TOOL REQUIREMENTS WORKSHEET (CONTINUED)

TOOL ITEM	PARAMETER	WEIGHT kg	WEIGHT lbs	VOLUME* cm³	VOLUME* in³	FOR USE BY PLANNER: NUMBER OF ITEMS REQUIRED	REMARKS	FOR USE BY PLANNER: TOTAL ITEM WEIGHT kg	TOTAL ITEM WEIGHT lbs	TOTAL ITEM VOLUME cm³	TOTAL ITEM VOLUME in³
SCREWDRIVING AND TORQUING TOOLS (cont'd.)											
PRY BAR	.76 m. (30 in.)	.68	1.50	386.8	23.6	1		.7	1.50	387	23.6
IMPACT TOOLS											
HAMMER AND MALLET	BALL PEEN	.27	.60	327.8	20.0						
	MALLET	.18	.40	401.6	24.5	1		.2	.40	402	24.5
CUTTING TOOLS											
DIAGONAL CUTTER, 20.3 cm. (8 in.)		.15	.33	98.3	6.0	1		.2	.33	98	6.0
SCISSOR		.07	.16	65.6	4.0						
KNIFE		.23	.50	31.1	1.9						
WIRE STRIPPER		.07	.16	82.0	5.0						
BOLT CUTTER		2.90	6.39	603.2	36.8	1		2.9	6.39	603	36.8
CABLE CUTTER		3.29	7.25	645.8	39.4						
*estimated from general consumer products							FOR USE BY PLANNER: TOTAL	3.9	8.6	1499	90.9

UNIT CONVERSIONS	m³	ft³
	.0015	.05

ORBITER OPTIONAL CONFIGURATION HARDWARE WORKSHEET

ITEM EQUIPMENT \ PARAMETER	WEIGHT* kg	WEIGHT* lbs	VOLUME* m^3	VOLUME* ft^3	FOR USE BY PLANNER: NUMBER OF REPRESS. REQUIRED	REMARKS	FOR USE BY PLANNER: TOTAL ITEM WEIGHT kg	TOTAL ITEM WEIGHT lbs	TOTAL ITEM VOLUME m^3	TOTAL ITEM VOLUME ft^3
AIRLOCK	~453.6	~1,000	4.25	150		UNDER STUDY--DECEMBER 1974				
• OXYGEN	1.2	2.7	--	--	4	PROVIDED FROM ORBITER TANKAGE	4.8	10.8	--	--
• NITROGEN	3.9	8.5	--	--	4	PROVIDED FROM ORBITER TANKAGE	15.6	34.0	--	--
EGRESS MODULE**	394.6	870.0	3.40	120		UNDER STUDY--DECEMBER 1974				
• OXYGEN	1.0	2.2	--	--		PROVIDED FROM ORBITER TANKAGE				
• NITROGEN	3.1	6.8	--	--		PROVIDED FROM ORBITER TANKAGE				
						FOR USE BY PLANNER: TOTALS ➧	20.4	44.8	--	--

*NOTE: Parameters are "best" estimates based on available Shuttle EVA information--December 1974.

**Proposed for EVA capability for manned payload interface to Orbiter.

EVA COST SUMMARY

PAYLOAD NAME EXTENDED X-RAY SURVEY AND LARGE HIGH ENERGY OBSERVATION D REVISITS

PAYLOAD NO. HE-03-R; HE-11-R TASK DESCRIPTION SERVICE AND REFURBISH BOTH PAYLOADS DURING ONE SHUTTLE (PIGGY-BACK) FLIGHT.

NUMBER CREWMEN REQUIRED 2 ESTIMATED TASK DURATION (HRS.) 4 NUMBER OF EVAs 6

COST ELEMENT	WEIGHT		VOLUME		REMARKS
	kg	lbs	m^3	ft^3	
SPACE SUIT ASSEMBLY					• SPARE SPACESUIT SUPPORT HARDWARE ONLY -- NO MAJOR REPLACEMENT ITEMS
COMPONENTS-HARDWARE	13.0	28.5	.13	4.70	
LIFE SUPPORT SYSTEM					• NO SPARE PLSS UNITS
COMPONENTS-HARDWARE	76.0	167.5	.04	1.50	
EVA WORKSTATION	22.7	50.0	.12	4.40	• TWO COMPLETE WORKSTATIONS PLUS EXTRA LIGHTS, TOOLS, TETHERS, ETC.
ANCILLARY EQUIPMENT	10.5	23.1	.03	1.10	
CREWMAN TRANSFER AIDS	9.8	21.6	.03	1.08	• SINGLE HANDRAILS AND HANDHOLDS
CARGO TRANSFER AIDS	3.6	8.0	.04	1.38	• ONE CLOTHESLINE SYSTEM

A.18

EVA COST SUMMARY (CONTINUED)

COST ELEMENT	WEIGHT		VOLUME		REMARKS
	kg	lbs	m^3	ft^3	
TOOLS	6.6	14.6	--	.19	• MISCELLANEOUS HAND TOOLS
"OPTIONAL" HARDWARE	20.3	44.8	--	--	• RECHARGE AIRLOCK 4 TIMES WITH O_2 AND N_2
MISCELLANEOUS EVA ITEMS	--	NONE	--	NONE	• NONE IDENTIFIED TO DATE

TOTAL EVA COST	WEIGHT: 162.5 (kg) 358.1 (lbs)	VOLUME: .39 (m^3) 14.35 (ft^3)	CREW TIME: 114* (hrs)

NOTES/CALCULATIONS

* INCLUDES 90 HOURS FOR ACTUAL TIME FOR 2 CREWMEN TO PREPARE FOR, COMPLETE EVA TASKS AND TERMINATE THE EVA MISSION PLUS 24 HOURS FOR EVA MONITORING FROM INSIDE THE CABIN. DOES NOT INCLUDE PREBREATHING TIME FOR EACH MISSION.

APPENDIX B

COST MODEL WORKSHEETS

EVA MISSION TIME WORKSHEET

PRE-EVA FUNCTION	CREW TIME (min.)	REMARKS/EXPLANATION
START PREBREATHE	5	Prebreathing equipment (rebreather, O_2 umbilical, and mask) is unstowed, connected and operationally checked. Crewman starts prebreathing and continues for up to 2 hours until the scheduled start of EVA preparation activities. During this 2-hour period, the crewman may perform required non-EVA related activities.
START EVA PREPARATION		
CABIN PREPARATION	10	Airlock and lower deck area are configured for life support equipment and suit donning. Donning aids, such as restraint devices and temporary stowage compartments, are unstowed and positioned, as required.
EQUIPMENT PREPARATION	15	Equipment required for EVA (i.e., suits, life support equipment, tethers, etc.) are unstowed and positioned for donning. Preliminary checkout of the equipment will be performed, as required.
SUIT DONNING	30	Inflight suits are doffed and stowed. EVA and ancillary equipment (i.e., crewman's waste management system and liquid cooling garment) are donned. Crewman connects to the airlock water cooling umbilicals.
ALSA DONNING	15	Life support equipment (backpack) donning would be completed if an integrated EMU is provided.
HELMET/GLOVE DONNING	15	After completion of prebreathe, crewman will doff the rebreather and don comm carrier, helmet and gloves. O_2 purge of EMU will then be performed.

EVA MISSION TIME (CONTINUED)

PRE-EVA FUNCTION	CREW TIME (min.)	REMARKS/EXPLANATION
COMMUNICATION CHECK	10	Comm check between the ALSAs and the Orbiter comm system is made. ALSA telemetry is checked. Backup ALSA comm modes are also checked.
INTEGRITY CHECK	5	An integrity check of the EMUs is performed prior to completion of airlock depress. This is a gross check of the EMU to verify that all connections are made and that leakage is acceptable
AIRLOCK DEPRESS	6	Airlock depress will be performed by the EVA crewman. Depress will be interrupted at least once to verify EMU and airlock integrity.
HATCH OPENING	4	After opening and securing outer airlock hatch, the crew will initiate start-up of ALSA cooling. After cooling has been established, crew will begin the EVA.
SUBTOTAL	110	EVA preparation only
FOR USE BY PLANNER		
EVA MISSION OPERATIONS TIME ESTIMATE		

POST-EVA FUNCTIONS	CREW TIME (min.)	REMARKS/EXPLANATION
HATCH CLOSING	5	After completion of EVA, crewman ingresses the airlock; ALSA cooling is shut down and outer airlock hatch closed.
AIRLOCK REPRESS	5	Crewman represses airlock and verifies airlock integrity.

EVA MISSION TIME (CONTINUED)

POST-EVA FUNCTIONS	CREW TIME (min.)	REMARKS/EXPLANATION
HELMET/GLOVE DOFFING	10	After suit pressure is equalized with ambient, crewman doffs and stows helmet and gloves and connects to the Orbiter water cooling system. The ALSA is deactivated.
ALSA DOFFING	15	ALSA is doffed and secured in the airlock. If integrated EMU is used, ALSA is doffed with the suit.
SUIT DOFFING	30	ALSA and suit are doffed and secured if an integrated EMU is used. Otherwise, suit is doffed during this period. Crewman also doffs ancillary suit equipment and dons flight suit. Suits and ancillary equipment are stowed unless suit drying is required.
ALSA RECHARGE	20	ALSA consumables are replaced during this period. ALSA is prepared and secured for next EVA. Loose equipment, such as tethers and cameras, is stowed.
SUIT DRYING	20	Suit drying is initiated, if required. If not required, suits and ancillary equipment are stowed, and the lower deck area/airlock are returned to pre-EVA configuration.
FOR USE BY PLANNER		
TOTAL		

NOTE: Timeline and sequences outlined are typical of those required for Shuttle EVA preparation and post-EVA activities. They are subject to change as equipment required to support EVA is better defined and procedures are optimized.

CREWMAN AND CARGO TRANSFER SYSTEM SELECTION

CARGO TRANSFER AIDS	CREWMAN ONLY	CARGO MASS AND VOLUME						REMARKS/APPLICATIONS
		CLASS I		CLASS II		CLASS III		
		SI	CONV.	SI	CONV.	SI	CONV.	
	NO CARGO	<73 kg. and <.3 m^3	<160 lbs. and <10 ft^3	73-730 kg. and .3-3.9 m^3	160-1600 lbs. and 10-40 ft^3	>730 kg. and >3.9 m^3	>1600 lbs. and >40 ft^3	
NO AIDS	yes	no		no		no		IVA ONLY--SHORT DISTANCES FREE FLOATING
VEHICLE EQUIPMENT	yes	yes		no		no		EXISTING VEHICLE EQUIPMENT ALONG TRANSLATION ROUTE OTHER THAN TRANSLATION AIDS
HANDHOLDS	yes	yes		no		no		PACKAGE TETHERED TO CREWMAN DURING TRANSFER
SINGLE TRANSLATION RAIL	yes	yes		no		no		USED ON SKYLAB--PACKAGE HANDHELD AND TETHERED TO CREWMAN
DUAL TRANSLATION RAIL	yes	yes		yes		no		USED ON SKYLAB--RATED HIGHLY BY CREWMEN
CLOTHESLINE SYSTEM	yes	yes		yes		no		MANUALLY ACTUATED ON SKYLAB
EXTENDIBLE BOOM	no	yes		yes		no		ELECTRICALLY ACTUATED CARGO BOOM
SHUTTLE MANIPULATOR ARMS	no	yes		yes		yes		REMOTELY ACTUATED FROM SHUTTLE CABIN
MANNED MANEUVERING UNIT	yes	yes		yes		requires study		PACKAGE ATTACHED TO MMU FOR FREE SPACE TRANSFER

SPACESUIT AND SUPPORT HARDWARE WORKSHEET

PARAMETER / SPACE SUIT ITEMS	WEIGHT		VOLUME		FOR USE BY PLANNER		REMARKS	FOR USE BY PLANNER			
					NUMBER OF EVA CREWMEN REQUIRED	NUMBER OF ITEMS REQUIRED		TOTAL ITEM WEIGHT		TOTAL ITEM VOLUME	
	kg	lbs	cm^3	ft^3				kg	lbs	cm^3	ft^3
TOTAL SPACE SUIT ASSEMBLY	31.2	68.8	TBD	TBD			1 REQUIRED PER CREWMAN--INCLUDES ALL ITEMS LISTED BELOW EXCEPT: (1) CREW PROVISIONS; AND (2) FLIGHT CREW EQUIPMENT				
• INTEGRATED TORSO LIMB SUIT ASSEMBLY	21.8	48.0	123,912	4.35			1 PER CREWMAN				
• LIQUID COOLING GARMENT (LCG)	1.6	3.6	7,080	.25			1 PER CREWMAN				
• HELMET	1.4	3.0	28,320	1.0			1 PER CREWMAN				
• EXTRAVEHICULAR VISOR ASSEMBLY (EVVA)	2.37	5.0	19,824	.70			1 PER CREWMAN				
• EV GLOVES	1.4	3.0	1,982	.07			1 PAIR PER CREWMAN				
• COMMUNICATION CARRIER ASSEMBLY (CCA)	.73	1.6	--	--			1 PER CREWMAN				
• IN-SUIT DRINKING DEVICE	.18	.4	2,832	.10			1 PER CREWMAN <u>PER EVA</u>				
• URINE COLLECTION DEVICE	.18	.4	5,664	.20			1 PER CREWMAN <u>PER EVA</u>				
• WATER FOR LCG	.45	1.0	--	--			INITIAL CHARGE ONLY				
• PERSONAL RADIATION DOSIMETER	.04	.1	85	.003			1 PER CREWMAN				
• PASSIVE RADIATION DOSIMETER	.04	.1	85	.003			1 PER CREWMAN				
• WRIST TETHER "D" RING	.14	.3	--	--			NONE REQUIRED--IS TASK DEPENDENT				
• IN-SUIT ELECTRICAL HARNESS	.18	.4	--	--			1 PER CREWMAN				
• BIOINSTRUMENTATION SYSTEM	.86	1.9	850	.03			1 PER CREWMAN				

SPACESUIT AND SUPPORT HARDWARE WORKSHEET (CONTINUED)

SPACE SUIT HARDWARE / PARAMETER	WEIGHT kg	WEIGHT lbs	VOLUME cm^3	VOLUME ft^3	FOR USE BY PLANNER: NUMBER OF EVA CREWMEN REQUIRED	FOR USE BY PLANNER: NUMBER OF ITEMS REQUIRED	REMARKS	FOR USE BY PLANNER: TOTAL ITEM WEIGHT kg	TOTAL ITEM WEIGHT lbs	TOTAL ITEM VOLUME cm^3	TOTAL ITEM VOLUME ft^3
CREW PROVISIONS	.68	1.5	850	.03			OPERATION OPTION--NOT INCLUDED IN SPACESUIT ASSEMBLY				
• COMFORT GLOVES	.04	.1	283	.01			OPTIONAL				
• WATCHBAND	.01	.02	283	.01			OPTIONAL				
• CHRONOGRAPH	.06	.13	283	.01			TASK DEPENDENT				
FLIGHT CREW EQUIPMENT	.65	1.34	736	.026			OPERATION OPTION--NOT INCLUDED IN SPACESUIT ASSEMBLY				
• PEN LIGHT	.17	.38	57	.002			TASK DEPENDENT				
• PENCIL	.02	.05	28	.001			TASK DEPENDENT				
• MARKER PEN	.01	.03	28	.001			TASK DEPENDENT				
• POUCH, SWISS ARMY KNIFE	.02	.05	28	.001			OPTIONAL				
• POCKET ASSY., SCISSORS	.04	.08	28	.001			OPTIONAL				
• POCKET ASSY., CHECKLIST	.19	.42	280	.010			TASK DEPENDENT				
• DATA LIST	.15	.33	280	.010			TASK DEPENDENT				
							FOR USE BY PLANNER TOTALS ➧				

EVA LIFE SUPPORT SYSTEM WORKSHEET

LIFE SUPPORT SYSTEM HARDWARE \ PARAMETER	WEIGHT *		VOLUME *		FOR USE BY PLANNER		REMARKS	FOR USE BY PLANNER			
					NUMBER OF EVA CREWMEN REQUIRED	NUMBER OF ITEMS REQUIRED		TOTAL ITEM WEIGHT		TOTAL ITEM VOLUME	
	kg	lbs	cm^3	ft^3				kg	lbs	cm^3	ft^3
ASTRONAUT LIFE SUPPORT ASSEMBLY (ALSA)	65.5	144.4	82,130	2.9			TOTAL OPERATIONAL UNIT. 1 REQUIRED PER CREWMAN FEED WATER INCLUDED.				
• PORTABLE LIFE SUPPORT SYSTEM (PLSS)	37.6	82.8	62,300	2.2			CONTROL ASSEMBLY INCLUDED				
- BATTERY	4.4	9.8	5,660	.2			1 PER CREWMAN--RECHARGED AFTER EACH USE				
- LiOH CARTRIDGE	2.5	5.5	3,400	.12			1 PER CREWMAN PER EVA				
• SECONDAY OXYGEN PACK (SOP)	10.4	23.0	16,426	.58			1 PER CREWMAN				
• OXYGEN FOR PLSS	.72	1.6	--	--			RECHARGED EACH EVA FROM ORBITER				
• OXYGEN FOR SOP	1.82	4.0	--	--			INITIAL CHARGE ONLY				
• TRANSPORT WATER FOR ALSA	.54	1.2	--	--			INITIAL CHARGE ONLY				
• FEED WATER FOR ALSA	4.5	10.0	--	--			RECHARGED EACH EVA FROM ORBITER				
• SERVICING AND COOLING UMBILICAL	2.9	6.5	8,500	.3			1 PER ALSA UNIT				
*NOTE: Parameters are "best" estimates based on available Shuttle EVA information--December 1974.							FOR USE BY PLANNER TOTALS ➧				

EVA SUPPORTING EQUIPMENT WORKSHEET

EQUIPMENT ITEMS \ PARAMETER	WEIGHT*		VOLUME*		FOR USE BY PLANNER		REMARKS	FOR USE BY PLANNER			
					NUMBER OF EVA CREWMEN REQUIRED	NUMBER OF ITEMS REQUIRED		TOTAL ITEM WEIGHT		TOTAL ITEM VOLUME	
	kg	lbs	cm^3	ft^3				kg	lbs	cm^3	ft^3
TRIPOD WORKSTATION	10.0	22.0	45,300	1.60			TOTAL WORKSTATION ASSEMBLY--STOWED				
• FOOT PLATE	2.3	5.0	6,230	.22			BASIC FOOT RESTRAINT				
• FOOT RESTRAINT ADAPTER	1.8	4.0	5,660	.20			TRIPOD MOUNTING UNIT				
• INGRESS AND STABILIZATION AIDS	2.0	4.5	4,250	.15			HANDRAIL/HANDHOLD FOR INGRESS/EGRESS				
• TOOL CONTAINER	2.0	4.5	8,500	.30			EXCLUDING TOOLS				
• PORTABLE LIGHT	1.4	3.0	2,830	.10							
• TEMPORARY STOWAGE ATTACHMENTS	.45	1.0	2,830	.10			FOR STOWING CARGO/MODULES AT WORKSITE				
WORKSTATION MODULAR-PORTABLE	11.3	25.0	62,300	2.2			TOTAL WORKSTATION ASSEMBLY--STOWED				
• BASE PLATE	2.5	5.5	6,800	.24			BASIC FOOT RESTRAINT				
• INGRESS RAILS	1.8	4.0	4,250	.15			HANDRAIL/HANDHOLD FOR INGRESS/EGRESS				
• TOOL CONTAINER	2.0	4.5	8,500	.30			EXCLUDING TOOLS				
• LIGHTS	1.4	3.0	2,830	.10							
• CAMERA MOUNT	.50	1.1	1,410	.05							
• EQUIPMENT HOOK	.64	1.4	1,410	.05			FOR TEMPORARY STOWAGE AT WORKSITE				
• TETHER	.22	.5	570	.02							
• ADAPTER PACKAGE	1.8	4.0	7,080	.25			FOR ATTACHING WORKSTATION TO VARIOUS WORKSITES				

EVA SUPPORTING EQUIPMENT WORKSHEET (CONTINUED)

EQUIPMENT ITEMS \ PARAMETER	WEIGHT*		VOLUME*		FOR USE BY PLANNER		REMARKS	FOR USE BY PLANNER			
					NUMBER OF EVA CREWMEN REQUIRED	NUMBER OF ITEMS REQUIRED		TOTAL ITEM WEIGHT		TOTAL ITEM VOLUME	
	kg	lbs	cm^3	ft^3				kg	lbs	cm^3	ft^3
• FOOT RESTRAINT	2.8	6.0	7,080	.25			FOOT RESTRAINTS ONLY MOUNTED PRIOR TO LAUNCH				
• WRIST TETHER	.17	.38	280	.01			OPTIONAL				
• WAIST TETHER	.23	.5	570	.02			OPTIONAL				
*NOTE: Parameters are "best" estimates based on available Shuttle information--December 1974.							FOR USE BY PLANNER TOTALS ➧				

CREWMAN TRANSLATION AND CARGO TRANSFER AIDS WORKSHEET

EQUIPMENT ITEMS \ PARAMETER	WEIGHT *		VOLUME *		FOR USE BY PLANNER		REMARKS	FOR USE BY PLANNER			
	kg	lbs	cm^3	ft^3	NUMBER OF EVA CREWMEN REQUIRED	NUMBER OF ITEMS REQUIRED		TOTAL ITEM WEIGHT kg	TOTAL ITEM WEIGHT lbs	TOTAL ITEM VOLUME cm^3	TOTAL ITEM VOLUME ft^3
CREWMAN TRANSLATION AIDS											
SINGLE TRANSLATION RAIL	.14 kg/m	.3 lb/ft	930 cm^3/m	.01 ft^3/ft			INCLUDES MOUNTING HARDWARE (PER LINEAR UNIT)				
DUAL TRANSLATION RAIL	.28 kg/m	.6 lb/ft	1860 cm^3/m	.02 ft^3/ft			INCLUDES MOUNTING HARDWARE (PER LINEAR UNIT)				
HANDHOLDS	.27	.60	2,270	.08			INCLUDES MOUNTING PROVISIONS				
MANNED MANEUVERING UNIT (MMU)	74.8	165	--	--			UNIT IN PRELIMINARY DESIGN--DECEMBER 1974				
• MMU SUPPORT EQUIPMENT	49.9	110	--	--			INCLUDES PROPELLANT SERVICING HARDWARE/PROVISIONS, ETC.				
PLANNER CALCULATIONS											
CARGO TRANSFER AIDS											
EXTENDIBLE BOOM	40.6	89.5	76,464	2.7			UNIT USED ON SKYLAB PROGRAM				
CLOTHESLINE SYSTEM	--	≥8.0	8,500	.3			UNIT USED ON SKYLAB PROGRAM				
REMOTE MANIPULATOR SYSTEM (RMS)	403.6	890.0	--	--			STOWAGE VOLUME SUPPLIED BY ORBITER				
*NOTE: Parameters are "best" estimates based on available Shuttle information--December 1974.							FOR USE BY PLANNER TOTALS ➧				

TOOL REQUIREMENTS WORKSHEET

TOOL ITEM \ PARAMETER		WEIGHT kg	WEIGHT lbs	VOLUME* cm^3	VOLUME* in^3	FOR USE BY PLANNER: NUMBER OF ITEMS REQUIRED	REMARKS	FOR USE BY PLANNER: TOTAL ITEM WEIGHT kg	TOTAL ITEM WEIGHT lbs	TOTAL ITEM VOLUME cm^3	TOTAL ITEM VOLUME in^3
SCREWDRIVING AND TORQUING TOOLS											
WRENCH, CRESCENT	15.2 cm. (6 in.)	.15	.32	73.8	4.5						
	20.3 cm. (8 in.)	.15	.32	98.3	6.0						
	25.4 cm. (10 in.)	.15	.34	163.9	10.0						
WRENCH, SOCKET SET	6 pc. set	.57	1.26	901.5	55.0						
	8 pc. set	.70	1.55	1311.2	80.0						
	10 pc. set	.82	1.80	1557.1	95.0						
PLIERS	slip joint	.15	.33	98.3	6.0						
	connector	.15	.32	98.3	6.0						
	needlenose	.15	.32	98.3	6.0						
	channel lock	.15	.33	114.7	7.0						
	vise grip	.15	.34	131.1	8.0						
*estimated from general consumer products							FOR USE BY PLANNER TOTAL ➧				

UNIT CONVERSIONS	m^3	ft^3

TOOL REQUIREMENTS WORKSHEET (CONTINUED)

TOOL ITEM \ PARAMETER		WEIGHT kg	WEIGHT lbs	VOLUME * cm^3	VOLUME * in^3	FOR USE BY PLANNER: NUMBER OF ITEMS REQUIRED	REMARKS	FOR USE BY PLANNER: TOTAL ITEM WEIGHT kg	TOTAL ITEM WEIGHT lbs	TOTAL ITEM VOLUME cm^3	TOTAL ITEM VOLUME in^3
SCREWDRIVING AND TORQUING TOOLS (cont'd.)											
SCREWDRIVERS (STANDARD OR PHILLIPS)	10.2 cm. (4 in.)	.08	.17	73.8	4.5						
	15.2 cm. (6 in.)	.10	.22	111.5	6.8						
	20.3 cm. (8 in.)	.13	.28	147.5	9.0						
	25.4 cm. (10 in.)	.15	.34	185.2	11.3						
	30.5 cm. (12 in.)	.17	.38	222.9	13.6						
WRENCH, OPEN/BOX END	5 pc. set	1.0	2.2	358.9	21.9						
	7 pc. set	1.5	3.2	519.6	31.7						
	9 pc. set	2.0	4.5	104.2	63.6						
ALLEN WRENCHES	3 pc. set	.11	.25	29.5	1.8						
	5 pc. set	.18	.40	63.9	3.9						
	7 pc. set	.27	.60	108.7	6.6						
*estimated from general consumer products							FOR USE BY PLANNER: TOTAL ➧				

UNIT CONVERSIONS	m^3	ft^3

TOOL REQUIREMENTS WORKSHEET (CONTINUED)

TOOL ITEM	PARAMETER	WEIGHT		VOLUME *		FOR USE BY PLANNER	REMARKS	FOR USE BY PLANNER			
								TOTAL ITEM WEIGHT		TOTAL ITEM VOLUME	
		kg	lbs	cm^3	in^3	NUMBER OF ITEMS REQUIRED		kg	lbs	cm^3	in^3
SCREWDRIVING AND TORQUING TOOLS (cont'd.)											
PRY BAR	.76 m. (30 in.)	.68	1.50	386.8	23.6						
IMPACT TOOLS											
HAMMER AND MALLET	BALL PEEN	.27	.60	327.8	20.0						
	MALLET	.18	.40	401.6	24.5						
CUTTING TOOLS											
DIAGONAL CUTTER, 20.3 cm. (8 in.)		.15	.33	98.3	6.0						
SCISSOR		.07	.16	65.6	4.0						
KNIFE		.23	.50	31.1	1.9						
WIRE STRIPPER		.07	.16	82.0	5.0						
BOLT CUTTER		2.90	6.39	603.2	36.8						
CABLE CUTTER		3.29	7.25	645.8	39.4						
*estimated from general consumer products							FOR USE BY PLANNER TOTAL ➧				

UNIT CONVERSIONS	m^3	ft^3

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ORBITER OPTIONAL CONFIGURATION HARDWARE WORKSHEET

ITEM EQUIPMENT \ PARAMETER	WEIGHT*		VOLUME*		FOR USE BY PLANNER	REMARKS	FOR USE BY PLANNER			
							TOTAL ITEM WEIGHT		TOTAL ITEM VOLUME	
	kg	lbs	m^3	ft^3	NUMBER OF REPRESS. REQUIRED		kg	lbs	m^3	ft^3
AIRLOCK	≈453.6	≈1,000	4.25	150		UNDER STUDY--DECEMBER 1974				
• OXYGEN	1.2	2.7	--	--		PROVIDED FROM ORBITER TANKAGE				
• NITROGEN	3.9	8.5	--	--		PROVIDED FROM ORBITER TANKAGE				
EGRESS MODULE**	394.6	870.0	3.40	120		UNDER STUDY--DECEMBER 1974				
• OXYGEN	1.0	2.2	--	--		PROVIDED FROM ORBITER TANKAGE				
• NITROGEN	3.1	6.8	--	--		PROVIDED FROM ORBITER TANKAGE				
						FOR USE BY PLANNER TOTALS				

*NOTE: Parameters are "best" estimates based on available Shuttle EVA information--December 1974.
**Proposed for EVA capability for manned payload interface to Orbiter.

EVA COST SUMMARY

PAYLOAD NAME ____________________

PAYLOAD NO. ____________ TASK DESCRIPTION ____________________

____

NUMBER CREWMEN REQUIRED ________ ESTIMATED TASK DURATION (HRS.) ________ NUMBER OF EVAs ________

COST ELEMENT	WEIGHT		VOLUME		REMARKS
	kg	lbs	m^3	ft^3	
SPACE SUIT ASSEMBLY					
COMPONENTS-HARDWARE					
LIFE SUPPORT SYSTEM					
COMPONENTS-HARDWARE					
EVA WORKSTATION					
ANCILLARY EQUIPMENT					
CREWMAN TRANSFER AIDS					
CARGO TRANSFER AIDS					

EVA COST SUMMARY (CONTINUED)

COST ELEMENT	WEIGHT		VOLUME		REMARKS
	kg	lbs	m^3	ft^3	
TOOLS					
"OPTIONAL" HARDWARE					
MISCELLANEOUS EVA ITEMS					
TOTAL EVA COST	WEIGHT: ________ (kg) ________ (lbs)		VOLUME: ________ (m^3) ________ (ft^3)		CREW TIME: ______ (hrs)
NOTES/CALCULATIONS					

APPENDIX C

COST MODEL UPDATING FORMS

EVA COST MODEL EQUIPMENT ADDITION SHEET

PARAMETER / EVA ITEM ADDED TO MODEL	WEIGHT		VOLUME		FOR USE BY PLANNER		REMARKS	FOR USE BY PLANNER			
					NUMBER OF EVA CREWMEN REQUIRED	NUMBER OF SPARES REQUIRED		TOTAL ITEM WEIGHT		TOTAL ITEM VOLUME	
	kg	lbs						kg	lbs		
							FOR USE BY PLANNER TOTALS ➧				

EVA COST MODEL MODIFICATION SHEET

EVA HARDWARE/ITEM MODIFICATION	PARAMETER WAS				CHANGE TO READ				REMARKS (Reason For Change)
	WEIGHT		VOLUME		WEIGHT		VOLUME		
	kg	lbs	m^3	ft^3	kg	lbs	m^3	ft^3	